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ETBE and TAME are used in small percentages along with a larger proportion of MTBE. Hence, vulnerability to ETBE and/or TAME would be determined on the basis of whether a source had an MTBE detection. Very little is known about the possible adverse health effects associated with either of these chemicals.

The proposed regulation would limit MTBE monitoring as an unregulated chemical to nontransient-noncommunity water systems because under this proposed regulation, community water systems would be conducting their monitoring under the secondary MCL requirements. Hence, only the nontransient-noncommunity water systems need to continue monitoring under this section.

Due to the recent findings of perchlorate in drinking water supplies in northern California (primarily eastern Sacramento County) and southern California (Los Angeles, San Bernardino, and Riverside Counties) by the Department through its Drinking Water Program, and the concern related to overall occurrence, the Department is proposing to add perchlorate to the list of unregulated chemicals for monitoring in order to better assess occurrence in California.

Perchlorate is an anion resulting from the chemical dissociation of industrial chemicals such as ammonium perchlorate, potassium perchlorate, and sodium perchlorate which have been in use for several decades in the manufacture of solid rocket fuel, munitions, and fireworks. Though little is known about perchlorate's behavior in the environment, it appears to be mobile in soils through which it migrates to groundwater, soluble in water, and extremely slow to biodegrade (or possibly not biodegradable). In February 1977, the Department initiated testing of highly vulnerable wells near suspect facilities and provided the supporting laboratory services; as of July 7, 1997, 232 wells from 48 systems had been sampled with perchlorate detected in 69 at levels greater than 4 ug/L, the detection limit for reporting purposes. It has also been found at low levels in the Colorado River as the result of the contamination of Lake Mead in Nevada.

The Department established a health-based action level for perchlorate of 18 ug/L in early 1997, based on its effects on the thyroid gland in a human study of non-carcinogenic effects.

The Department proposes to correct an editorial error in table 64450-B: the synonym for 1,2,3-Trichlorobenzene should read "vis-Trichlorobenzene" instead of "vic-Trichlorobenzene". The latter is a typo and is not correct.

#### 64450.1. Monitoring – Unregulated Chemicals

The purpose of this section is to establish the monitoring requirements and criteria for monitoring waivers and exemptions for unregulated chemicals. The Department is proposing to amend this section as follows:

Subsection (a) would be amended to incorporate the requirement that monitoring be repeated at five-year intervals for conformance with federal regulations (40 CFR Section

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141.40(i), Federal Register 52, 25715, July 8, 1987). Subsection (a) would also be amended for clarification to incorporate monitoring frequency and the specification regarding using the same sites unless Department approval is obtained from subsection (b). Specifically, paragraph (a)(1) would specify the tables of chemicals for which monitoring frequency differs according to type of source and would incorporate the requirements from the existing paragraph (a)(1) and (a)(2). The proposed paragraph (a)(2) would incorporate the existing monitoring requirement from subsection (b) for Table 64450-C and establish that monitoring frequency for perchlorate as well. The Department believes that quarterly monitoring rather than a single sample is more appropriate for perchlorate data collection because the data collected since February 1977 has demonstrated that results at a single source can vary considerably. Subsection (3) would be amended to establish an appropriate grandfathered data date for ETBE, TAME, and perchlorate data. 1993 would provide for data up to five years old to be used with repeat monitoring five years from the date of that data. The word "initial" would be added for clarification. The caveat that there should have been no detections in order to grandfather data is not actually applicable since unregulated chemical monitoring does not specify follow-up procedures for positive findings. Paragraph (a)(4) is a requirement from subsection (b), placed here for continuity.

Subsection (b) would be amended to delete the obsolete deadline for sampling and the redundant (to subsection (a)) requirement for "representative samples". The phrase "by the Department" would be added to clarify how a water system is determined to be nonvulnerable and the proposed table 64450-D would be added.

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## Appendix 1

List of Commentators  
Public Comment Period Ending September 8, 1998  
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<i>Reference #</i>	<i>Commentator Name and Representation</i>
1	John Kneiss, Director, Health Sciences and Product Stewardship Oxygenated Fuels Association
2	Gene Livingston and S. Craig Hunter Livingston & Mattesich Law Corp. Attorneys for the Oxygenated Fuels Association
3	Jeff Sickenger, Environmental Issues Coordinator Western States Petroleum Association (WSPA)
4	Michael J. McGuire, Ph.D. McGuire Environmental Consultants, Inc.
5	John McKnight, Director of Environmental and Safety Compliance National Marine Manufacturers Association
6	Margaret H. Nellor, Head Monitoring Section County Sanitation Districts of Los Angeles County
7	Mark Bushler, Director of Water Quality Metropolitan Water District of Southern California
8	Andrew DeGraca, P.E., Water Quality Bureau Manager Public Utilities Commission, City and County of San Francisco
9	Nira Yamachika, Director of Water Quality Orange County Water District
10	Dan Smith, Manager of Regulatory Affairs Association of California Water Agencies (ACWA)
11	Gilbert M. Borbos, Jr., P.E., Utilities Manager City of Santa Monica Utilities Division

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### Response to Public Comments on R-44-97

No request for a public hearing pursuant to Government Code 11346.8 was received in a timely manner.

The following responses to public comments on R-44-97 are organized as follows: "Appropriate Threshold Level" includes comments/responses related to the appropriate level to use to establish the MCL (lowest level of detection in a study vs geometric mean of the levels detected in the study); "Appropriate Criteria" addresses comments/responses related to consumer acceptance criteria; "Good Science" includes comments/responses related to the scientific basis for the proposed MCL; "Cost" includes any comments related to the cost of the regulation; and "Miscellaneous" includes comments not fitting in any of the above categories.

#### Appropriate Threshold Level

Commentator 1 stated that the Department inaccurately defined the threshold concentration as the lowest concentration detected by an assessor. Specific points were that the Young study included results expressed not only as the lowest concentrations detected, but also as geometric means; that the ASTM method E-679 defines detection threshold differently from the Department; and that the "Standard Methods for the Examination of Water and Wastewater states that the Threshold Odor Number (TON) is the concentration of an odorant where three dilutions will produce no perceptible odor." The Department would like to note that the definition ascribed to Standard Methods is incorrectly stated, by the commentator; the definition is, "The 'threshold odor number,' designated by the abbreviation TON, is the greatest dilution of sample with odor-free water yielding a definitely perceptible odor." (Standard Methods, 19<sup>th</sup> edition, p. 2-13) Further, the Department would like to cite the dictionary's definition for "threshold": "The point at which a stimulus, as of a nerve or muscle, just produces a response." (Funk and Wagnalls, 1968) The Department is using the term "threshold for odor and taste" in the sense defined in the dictionary, i.e., as the lowest concentration at which a sensory response of smell or taste occurs.

Commentators 1 and 4 stated that the Department should use the geometric mean to establish the MCL, citing the ASTM Standard. Commentator 1 also referenced the opinion of the Expert Advisory Panel that it had used for the Malcolm Pirnie, Inc., study (1998): "...using the geometric mean to support a secondary MCL is a scientifically justifiable approach". However, the commentator has not demonstrated why a geometric mean is more scientifically justifiable than the lowest level detected. Although, the studies that investigated MTBE odor and taste present their results in terms of geometric means of the study panel, as well as lowest levels detected, the geometric mean simply indicates that the "average" person would sense MTBE at that level, based on that study's results in which half the panel reported sensing MTBE in drinking water at that level and half did not.

The Department believes that in setting a drinking water standard, it should strive to meet a higher goal for public welfare protection than only half the population.

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Clearly, Health & Safety Code §116275(d) indicates the application of a secondary MCL to any contaminant in drinking water that "may cause a substantial number of persons served by the public water system to discontinue its use," and directs the Department to a lower level than the geometric mean for sensation of MTBE's odor or taste. Setting the standard at 5 ppb enables the water supply to remain wholesome, and protects a larger proportion of the population from the taste and odor of MTBE. Since only a small change in the proportion of the population can account for many millions of people when applied to California, it is important that such a standard be set as low as is reasonable. The Department would not be acting in the best interests of the public if it were to set a standard that could result in half the population being at risk of smelling MTBE in their drinking water. Neither would such an approach be consistent with the public welfare policy of providing protection for the entire population to the extent that that is feasible.

Commentator 1 suggested that the 7 detections at 2.5 ppb in the Orange County Water District study were likely to have been made by the same tester and that since the tester did not always detect down to this level, this reinforced the Young study statement regarding variation in sensitivity of individuals. Following this line of reasoning, the commentator then concluded that it was inappropriate to base the threshold on a single individual. The commentator has no way of knowing whether all these detections were by the same panelist, because this information was not provided in the study report. Further, a subsequent study (Shen *et al.*, 1997) found detections down to 2.5 ppb and not all by the same tester. Hence, the Department did not base the MCL on a single individual's sensitivity to MTBE in water.

Commentator 1 stated that the Young study does not support a secondary MCL of 5 ppb, because no panelists could detect MTBE at 5 ppb. Commentator 4 stated that the proposed MCL was below the lowest detectable level for a compound in a panel test. Both of these commentators appear to not be aware of the studies in which panelists detected levels less than 5 ppb. Although no panelists in the Young study detected at 5 ppb, the 1997 study by Shen *et al.* showed MTBE odor detected by individual panelists at levels as low as 2.5 µg/L. The lowest concentrations of MTBE in water at which odor was detected among the 24 test runs in the 1998 Orange County Water District study were: 2.5 ppb (6/24, 25 percent), 5 ppb (4/24, 17 percent), 10 ppb (7/24, 29 percent), 20 ppb (2/24, 8 percent), or 30 ppb (1/24, 4 percent). No concentration lower than 2.5 ppb was tested in either study. Hence, the highest concentration that would not be detected by an individual under conditions of these studies is unknown (but less than 2.5 µg/L.). Subsequently, the Malcolm Pirnie study results showed 10 of the 57 panelists able to sense MTBE odor down to 2 ppb.

The Department would like to note that under the secondary MCL regulations (22 CCR Section 64449), a water utility may obtain a waiver for the MTBE secondary MCL if it were able to document that the community being served by the water utility "accepted" the odor and/or taste of MTBE in preference to paying to remove it. This would address issues related to local sensitivities, water quality, and economic considerations.

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### Appropriate Criteria

Several commentators addressed the criteria used to determine an acceptable level for the MCL related to consumer acceptance and objectionable odors. In addition, commentator 3 stated that the Department should establish objective secondary standard setting criteria. Commentator 7 urged the Department to set a standard that protects consumers from objectionable water and stated that reliable threshold data and a determination of an objectionable concentration level are critical in establishing the MCL. Commentator 10 stated that it believed that the studies available support a conservative standard and that it supports the use of good science in rulemaking. The Department agrees with these comments and believes that they have been addressed during the standard setting process, as well as below.

Commentator 1 stated that the Department did not discuss "consumer acceptability" in the documentation, yet stated a goal of ensuring that consumers were not exposed to objectionable taste and odor related to MTBE in their drinking water. The commentator went on to note that common descriptor words used for MTBE in taste and odor tests were "estery," "vanilla," "sweet," "bitter" and "sweet solvent" and, hence, the taste or odor "is likely not objectionable, and would not, therefore, affect consumer acceptability of drinking water." The Department believes that its "goal" reflects the appropriate public health agency policy position and, therefore, did not discuss whether such tastes or odors would be "acceptable" to the consumer. The commentator implies that because testers selected the words "vanilla" and "sweet" and "sweet solvent" to describe the tastes and odors they were detecting, that they would not object to drinking such waters from their home taps. From the Department's experience, any indication in a drinking water that a contaminant is present is generally highly objectionable to the consumer, even if reassured that no health risk is posed. In addressing the effect of a contaminant on odor or taste, the Department would not give deference to a pleasant tasting contaminant over one that is less pleasant, nor to a level of a specific contaminant that is pleasant tasting over a level that is not. Furthermore, the public will find objectionable any odor and taste that it has learned to identify with MTBE or any other chemical. In addition, existing regulations allow water systems the option of requesting a waiver from compliance with the secondary MCL if their customers accept drinking water exceeding the MCL.

Commentator 2 stated that studies conclude that odors at levels greater than 5 ppb are not objectionable. The commentator does not specify to which studies he refers. It may be that he is referring to the above descriptors used by panelists and has concluded that they would not object to having the test waters coming from their home taps; there are no data to substantiate this conclusion.

Commentator 2 stated that the Department exceeded the scope of Health and Safety Code sections 116275(d) and 116610(d), both of which provide criteria for establishing a secondary MCL for MTBE. The first section mandates that the Department set secondary MCLs to protect public welfare for any contaminant that adversely affects the odor or appearance, causes a substantial number of persons to discontinue use or otherwise adversely affects public welfare." The second section mandates that the

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MTBE secondary MCL be set at a level that does not exceed the consumer acceptance level. The Department believes that it has acted consistently with these mandates: Based on the studies available, MTBE does adversely affect the odor (as well as taste) of water, could cause a substantial number of persons to discontinue use, and, by its presence, could adversely affect public welfare. Based on its role as a public health agency, the Department believes that establishing an MCL for MTBE of 5 ppb will ensure that the consumer acceptance level of the large majority of the population is addressed. As previously noted the MCL can be waived if consumers accept drinking water in excess of the MCL.

Commentator 2 stated that the Department should look for guidance to the 'counterpart federal scheme, and to the interpretations thereof...' because the California statutes were passed to carry out the federal mandates. Commentator 3 stated that the Department should look to other federal, state and local agency programs. When appropriate, the Department does refer to federal guidance. However, California is not precluded from adopting more stringent standards than those recommended at the federal level. In fact, California has adopted several MCLs that are more stringent than the federal counterpart. In the case of MTBE, the Department believes that an MCL which is more stringent than the federal guidance is necessary to ensure public acceptance and protect against adverse affects to the public welfare.

#### Good Science

Commentators 7 and 10 stated that the Department should use "good science" in establishing the MCL. Commentators 1, 2 and 3 noted that the Department mentioned only two MTBE taste and odor studies; the first commentator listed four others. Commentator 3 stated that the Department did not take into account the Malcolm Pirnie study. Although the Department did not mention the Arco and API studies, it had reviewed the findings of both and gave less weight to them because the lower levels of sensation detection were established by statistical projection as opposed to the Shen, *et al.*, 1997 study and the Young, *et al.* study. The Shen and Young studies exposed panelists to lower concentrations of MTBE. The Malcolm Pirnie study was not completed and was not available at the time the regulation package was developed. However, the Malcolm Pirnie study was submitted during the comment period and was reviewed. The Department believes that the Malcolm Pirnie study supports establishing an MCL of 5 ppb.

Commentator 2 stated that the Department has failed to establish a scientific necessity for an MCL that is so restrictive and that "has relied on a single, fatally flawed taste and odor test", and that it has "cherry-picked" the Young study findings, ignoring those portions that compel a higher standard. This commentator also stated that the Malcolm Pirnie study should be the basis of a 15 ppb standard since its testers consisted of untrained California residents. Commentator 3 noted the lack of documentation of consumer complaints for MTBE in drinking water and that the available taste and odor studies did not use naturally occurring substances common to California groundwater supplies which can mask MTBE. These comments are addressed in the paragraphs below.

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Commentator 1 provided a copy of the Malcolm Pirnie study that it funded. A number of commentators (1, 2, 3, 4, and 6) recommended that the Department base the MCL on this study. Commentator 1 made the following statements regarding the study: That it is the only one conducted on consumer panelists with a large statistical population, that study results should be more representative of the general California population than those of other studies, that the results fall within the same range as those from other studies with one exception, that the commentator's Expert Advisory Panel agreed that this was the best study, and that the study's geometric mean should be used as the basis for the MCL instead of the lowest level detected. The Department has reviewed the Malcolm Pirnie study, which used a panel of 57 subjects, roughly half male and half female, from 18 to 65 years of age. Panelists were exposed to MTBE at concentrations in water from 2 to 100 ppb.

Based on the data from this study (Table 3.2), the lowest concentration detected by individual panelists was 2 ppb MTBE, and this was sensed by 10 of 57 panelists (18 percent). The percentage of panelists indicating they sensed MTBE increased with increasing MTBE concentration, as follows: 6 ppb (18/57, 32 percent), 10 ppb (22/57, 39 percent), 18 ppb (31/57, 54 percent), 30 ppb (38/57, 67 percent), 60 ppb (44/57, 77 percent), and 100 ppb (49/57, 86 percent). The geometric mean of the data was 14.5 ppb.

These data clearly indicate that using the geometric mean as the basis for the MCL would potentially result in a much higher percentage of consumers detecting MTBE than at the proposed MCL of 5 ppb. Therefore, the Department does not believe that using the geometric mean would ensure consumer acceptance or avoid adversely affecting the public welfare.

Commentator 1 stated that a statistical analysis of the Malcolm Pirnie data by Dr. Richard Berk of UCLA showed that any correct detection below 22 ppb was the result of either guessing or identification by the most sensitive 5% of the population. It is not clear how Dr. Berk drew this conclusion. When it received the report by Malcolm Pirnie in July 1998, the Department requested information on the methods used by the consultant to estimate guessing, since, as Dr. Beck suggested in the Malcolm Pirnie report, the basic method used in the study (ASTM Method E679-91) appears to already account for guessing. No additional information was received by the Department prior to the close of the comment period.

The ASTM approach to guessing would not consider a positive sensation of MTBE to be "positive" if a "negative" occurred at a higher concentration. For example, if a panelist reported MTBE at 2 ppb, but not at 3.5 ppb, and then at 5, 10, and higher concentrations, that panelist's "threshold" would be 5 ppb, not 2 ppb. Making these adjustments (using the information presented in Table 3.2 of the Malcolm Pirnie report), the number of panelists sensing various levels of MTBE becomes: 2 ppb (10/57, or 18 percent, 3.5 ppb (10+0 [panelists sensing MTBE at this concentration plus those at lower concentrations]=10/57, 18 percent) 6 ppb (10+0+8=18/57, 32 percent), 10 ppb (10+0+8+4=22/57, 39 percent), 18 ppb (10+0+8+4+9=31/57, 54 percent), 30 ppb

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(10+0+8+4+9+7=38/57, 67 percent), 60 ppb (10+0+8+4+9+7+6=44/57, 77 percent), and 100 ppb (10+0+8+4+9+7+6+5=49/57, 86 percent).

The Malcolm Pirnie study treated 8 of the 57 panelists as not having identified MTBE as being present at even 100 ppb, and assigned them a value of 132.3 as an individual threshold. However, these eight panelists also indicated MTBE as being present in one or more tests lower than 100 ppb. Specifically the eight panelists gave a positive response in the following number of tests (out of eight different MTBE concentrations): 3, 2, 4, 5, 3, 1, 3, and 3. Two of the eight identified MTBE at 2 ppb, and the rest at higher concentrations, though all were assigned the 132.3-value.

In summary, the study by Malcolm Pirnie found a geometric mean of 14.5 ppb for MTBE odor sensation, while a significant fraction of the 57-member panel indicated that MTBE could be sensed at levels as low as 2 ppb. These results were not inconsistent with other studies reviewed and, therefore, they suggest that even if some of the other studies had limitations, their results were within a reasonable range and definitely not inapplicable to California waters and consumers. Hence, the Department has concluded that the Malcolm Pirnie study further supports the proposed MCL of 5 ppb.

Clearly, the primary point of difference between the commentators and the Department relates to whether the standard should be set to protect half the population or a larger portion of the population. As stated above under "Appropriate Level", the Department, as a public health agency, must act to protect the greatest portion of the consumer population as is feasible, and, therefore, the Department believes establishing the secondary MCL at 5 ppb is appropriate.

Commentator 1 stated that USEPA "urged water utilities" in 1989 to use the 3 TON standard as a criteria for odor in finished drinking water, i.e., a concentration of odorant 3 times greater than the maximum level of no perception, but the Department has used a 1 TON standard which is "needlessly conservative". The commentator also stated that the Department is establishing a dangerous precedent of setting chemical-specific standards based on criteria that is not accepted by any scientific body; both ASTM and Standard Methods specify a taste and odor result that is greater than the lowest perceived concentration detectable by a single panel member; and the Department should use a rigorous scientific method. The context for the statement attributed to USEPA is not provided, so the Department is unable to adequately address this comment. The commentator's comment regarding establishing a dangerous precedent implies that ASTM and Standard Methods provide criteria for setting a secondary standard, which they do not. These methods simply address procedures for determining odor thresholds in water samples. For example the TON is conducted by water treatment operators who have developed expertise by repetitively conducting the same test on the same water to identify a known sensation.

When it began the process of establishing a secondary MCL, the Department initially considered the study by Young et al., 1996, to be the most appropriate for establishing a concentration at which no odor would be detected. The 1997 study by Shen et al.,

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suggested that MTBE could be sensed at lower levels, less than 2.5 ppb, but the Department felt that given the attention focused on MTBE and problems of local ground water contamination, there might have been some unintentional bias that entered into the California study, compared to the British study that investigated MTBE along with many other substances. In addition, the Department also felt that intralaboratory contamination issues should be addressed; within that context, a secondary standard lower than 2 ppb would be too restrictive. The Department believed that an MCL of 2 ppb would bring with it a potential for false positives and a need for drinking water systems to investigate contamination where there might be none.

However, with the additional studies by Dale *et al.*, (1997), Shen *et al.*, (1998), and Malcolm Pirnie the Department recognizes that certain individuals, and in some cases a fairly high proportion of them, are able to sense MTBE at levels as low as 2 ppb.

Consequently, based on a need to protect the public welfare, to protect against the odor and taste of MTBE, and to assure that a substantial number of persons served by the public water system would not discontinue their use of drinking water from public water systems, and considering the totality of information from MTBE odor and taste studies, the Department believes that it could justify a level of MTBE lower than the proposed 5 ppb. Commentator 4 claimed he could design studies to include sensitive people able to detect very low levels of MTBE and wanted to know how the Department would proceed if it had such data. In this case, the Department did consider revising the proposed secondary MCL downward to 1 ppb, based on the more recent studies, in order to protect a larger portion of the population than would be protected by 5 ppb. However, the Department decided not to do so, because the lower level would raise the potential for false positives and consequently unnecessary investigations of contaminant sources. Hence, more data at lower levels does not necessarily lead to a lower standard since there are other considerations; however, given the Department's policy related to protecting the largest percentage of the population as is feasible, the additional studies providing data at low levels further substantiates the need to set the MCL no higher than 5 ppb.

#### Cost

Commentator 3 stated that the Department did not consider the cost to public water systems to upgrade their facilities in order to comply with the proposed secondary MCL. At the time that the regulation package was developed, there were no active drinking water sources that would have been out of compliance with the proposed standard. Since the costs of a regulation are generally developed within the context of known parameters, not hypothetical, the Department did not address this issue. Further, based on data collected to date and the actions taken by the few utilities with MTBE-contaminated sources, the Department does not anticipate that many drinking water sources will actually require treatment.

Commentator 3 stated that the Department did not address whether the proposed MCL would impose a mandate of a local agency to provide a new or increased level of service and that it should have done so since improved water quality could constitute an

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increased level of service. The Department did address this issue in the "Local Mandate Determination" and determined that any costs that might result would not be due to a "new program or higher level of service" within the meaning of Article XIII B, Section 16 of the California Constitution because they apply generally to all individuals and entities that operate public water systems in California and do not impose unique requirements on local governments.

Commentator 3 stated that the Department ignored costs associated with anticipated widespread application of the proposed MCL as a default cleanup level by regional and local water agencies. The Commentator further stated that the Department was required to determine the cost to private businesses to remediate MTBE impacted sites and attached a cost analysis comparing the cost increase at leaking underground storage tank remediation sites at the proposed 5 ppb MCL and the Malcolm Pirnie recommended MCL of 15 ppb. Commentator 6 stated that the Department failed to address the impact on wastewater or reclaimed water sources. Since the proposed MCL regulation is directly applicable to only public drinking water systems, the Department is not required to address any other costs than those resulting from that application. Furthermore, to do so is speculative and becomes more so as the effect ripples out from the regulated community. There would be no end to such an analysis.

Commentator 3 stated that the Department did not determine the fiscal impact on California businesses, then added that the Department concluded that no jobs would be eliminated. The Department refers the commentator to the "Fiscal Impact" statement in which it addressed the fiscal impact on the businesses directly impacted by the regulation (i.e., private drinking water systems) and the "Business Impact" statement in the proposed regulation package. The conclusion that no jobs would be eliminated is accurate in terms of those to which this regulation directly applies. As noted above, the Department is only required to estimate the fiscal impact to those businesses to which the regulation directly applies.

Commentator 3 did not agree with the Department that this regulation would not result in the creation or elimination of water systems. The Department's experience with previously adopted MCL regulations is that water systems are not eliminated as a result, but rather, approaches to compliance are worked out since the community needing the water supply continues to exist.

Commentator 3 stated that the waiver procedures for secondary standards would have no practical application if the economic impact considerations were limited to incremental monitoring costs. The commentator apparently does not understand that the waiver considerations address only the cost of treatment, not monitoring costs.

Commentator 3 stated that the Department provided no guidance on determining what level of incremental cost is appropriate to meet the secondary MTBE MCL. The Department assumes that the commentator is suggesting that the Department should have "appropriate level of cost" criteria for compliance with a secondary MCL such as the criteria that EPA has developed for primary MCL treatment costs to consider the impact

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on smaller water systems. The Department does not feel that such an analysis is necessary since existing regulations allow for waivers to secondary MCLS. One of the factors considered by the customers in determining whether to have the water system seek a waiver is the cost to meet the secondary standard.

Commentator 3 stated that the Department did not analyze any alternatives to the proposed standard, nor analyze the economic impact of potential alternatives. As noted above, the Department approached the standard-setting process from a public welfare perspective related to the provision of a water supply that is pure, wholesome and potable. Analysis of available data indicated that the appropriate standard to meet that objective was 5 ppb. The Department did consider other alternative levels but determined that no other alternative level would feasibly meet that public welfare objective.

Commentator 3 stated that the Department's "implicit goal of protecting 100% of the population is inconsistent with statutory requirements, unnecessarily conservative and unreasonable from an economic impact perspective." The Department goal is to achieve protection for the greatest portion of the population that is feasible. The Department believes that the proposed MCL achieves that goal. The commentator's concern related to economic impact is primarily associated with the potential impact on dischargers if the MCL is utilized as criteria by the Regional Boards and other agencies. The Department's responsibility is to ensure that drinking water quality is protected, not try to anticipate if, how, when, or where the drinking water standards may be applied beyond the public drinking water systems that are addressed in the regulation.

Commentator 5 stated that a stringent standard would have serious economic consequences for small California recreational marine dealers, far exceeding the fiscal impacts noted in the regulation package. The Department is aware that secondary and tertiary impacts may occur although these impacts are not addressed in the analysis since marine dealers are not directly affected by this regulation, i.e., the regulation does not contain any requirements with which the marine dealers must comply.

Commentator 8 stated that the Department did not address the cost of ETBE, perchlorate, and TAME analyses in the business impact section. The Department definitely addressed this cost in the business impact section; specifically mentioning anticipated percentages of systems expected to monitor, the monitoring cost, etc.

Commentator 8 stated that the fiscal impact section's overall governmental estimates appear to be low, but provided no specific comments. The Department followed normal procedures for developing these costs which are basically a function of the number of water systems operating under government agencies. As far as the Department knows, the cost estimates represent a reasonable estimate.

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#### Miscellaneous Comments

Commentator 1 noted that the Department stated that the Young study methods and reported findings indicate that at the next lower concentration, estimated at 5 and 12.5 ppb for odor and taste, no MTBE was detected by the assessors; the commentator believes that the second level should be 15, based on the dilutions. The Department agrees that this could be possible but it is not possible to conclude that based on the data available.

Commentator 1 noted that the Department incorrectly stated that Orange County Water District found geometric means of 13.5 to 43.5 ppb and that the second mean was actually 45.4 ppb. The Department agrees.

Commentator 9 asked the Department to specify detection limits for purposes of reporting (DLRs) for MTBE, TAME, ETBE, and perchlorate. The Department has incorporated DLRs for these chemicals in its laboratory data reporting process. However, the Department does not put DLRs in regulation until a primary MCL is adopted. It is anticipated that a DLR of 3 ppb will be proposed when the primary MCL for MTBE is proposed.

Commentator 9 asked the Department for dates to initiate or complete MTBE, TAME, ETBE, and perchlorate monitoring. MTBE monitoring should be coordinated with other secondary MCL monitoring done by a system. TAME, ETBE and perchlorate are required only for vulnerable sources; monitoring for TAME and ETBE can be coordinated with any other volatile organic chemical monitoring being conducted by the system, while perchlorate requires a unique method and, if required to monitor, a system should move to do so as directed by the Department. Guidance on these matters will be provided.

Commentator 9 suggested that if MTBE is detected, repeat monitoring should be required to track MTBE migration and requested repeat monitoring guidance. Secondary MCL monitoring does not include repeat monitoring because it is a non-health issue. A water system may conduct this type of monitoring if it wishes.

Commentator 11 expressed support for the proposed MCL of 5 ppb and monitoring for TAME, ETBE, and perchlorate.

Commentator 6 recommended that the Department create a policy for reclaimed water dischargers for compliance or exempt reclaimed water from the secondary drinking water provisions unless direct potable reuse is planned. The Department reminds the commentator that this regulation does not require compliance from reclaimed water dischargers.

Commentator 6 stated that the Department needs to address reclaimed water issues related to the proposed MCL, as well as revisit older MCLs. Since this regulation applies

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directly to only public drinking water systems, addressing reclaimed water issues within this context would not be appropriate. However, when the Department proposes regulations for reclaimed water, under separate statutory authority, the commentator should make a point of bringing up these issues.

Commentator 8 stated that he supports the use of grandfathered data; the Department appreciates this information.

Commentator 8 is not clear whether one year of quarterly samples per site is required every five years or one year of quarterly samples per site initially and then only one sample per site every five years thereafter (reference section 64450.1). Initial and repeat monitoring at five-year intervals follow the same sampling scenario in terms of number of samples. The Department believes that the regulation text is clear on this point.

Commentator 5 requested that the Department hold a public hearing to provide an opportunity for further comment. Unfortunately, this request was not received until the close of the comment period on September 8, 1998. In order to have been considered, pursuant to Government Code 11346.8, the request would have had to have been received by the Office of Regulations no later than 15 days prior to the close of the comment period. This deadline was noted in the notice for this regulation package.

Commentators 2 and 5 recommended that the Department utilize the USEPA nationwide drinking water advisory recommending a limit value range of 20 to 40 ppb. In 1997, USEPA published this consumer acceptance advisory, "...recognizing that some people may detect the chemical below this range." The Department believes that the concentration of MTBE at the EPA advisory level is too high to protect customers from the undesirable odor and taste effects of MTBE in drinking water, particularly in view of the 1998 studies by Shen *et al*, and Malcolm Pirnie, Inc., cited above.

Commentator 4 stated that the Department "opens itself to concerns that can be raised due to bias" since the Young study used to derive the MCL had an all-female panel. Except for this commentator, no one has made any reference to the all-female panel. The Young study was a scientific study using a panel of trained testers who happened to be all-female. The Department is not aware of any information that indicates females are more or less sensitive to MTBE than males. Therefore, the Department does not believe that there is any issue here.

Commentator 3 recommended that the Department give flexibility to water utilities by establishing a range of concentrations as a function of geographic and other circumstances that may affect water quality rather than a fixed standard. The Department does not believe that such an approach would be appropriate for a chemical contaminant affecting the odor of a drinking water supply. The commentator suggested that an appropriate concentration within the range could be selected depending on the specific circumstances of the water supply, but did not elaborate as to what those might be or how such a standard could be implemented. As noted previously, existing regulations provide

R-44-97

for flexibility by allowing waivers from secondary MCLS based on consumer acceptance and cost of compliance.

Commentator 3 recommended that the Department subject the proposed secondary MCL to a formal peer review process prior to adoption. The Department has found that the public comment period for proposed regulations for both primary and secondary MCLs is quite adequate as a review process.

Commentator 3 stated that the Department should establish implementation guidelines for drinking water well treatment and site remediation and preferably include them in the regulations. When the Department proposes a primary MCL for MTBE, it will also propose a best available technology (BAT); at this time, air stripping is the only technology that meets the statutory criteria for BAT in California. The Department is responsible for drinking water treatment, not site remediation; hence, it would be inappropriate to address site remediation in regulations promulgated by the Department.

**Exhibit F**  
**Lawless Report**



Feb 6 2009  
7:00PM

UNITED STATES DISTRICT COURT  
SOUTHERN DISTRICT OF NEW YORK

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In Re: Methyl Tertiary Butyl Ether ("MtBE")  
Products Liability Litigation

MDL No. 1358  
Master File C.A. No.  
1:00-1898 (SAS)

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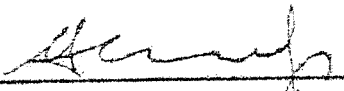
This document relates to the following case:  
*City of New York v. Amerada Hess Corp., et al.*,  
04 Civ. 3417

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EXPERT REPORT OF HARRY T. LAWLESS, Ph.D.

3066 Traddell Road  
Ithaca, NY 14850

February 5, 2009

  
\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

EXPERT REPORT OF HARRY T. LAWLESS, Ph.D.  
February 6, 2009

**I. Experience and qualifications**

1. I am currently Professor in the Food Science Department of Cornell University, where I specialize in teaching sensory evaluation methods and performing research on taste and smell. I am a member of the Graduate Field of Food Science and the Graduate Field of Psychology. I have been a member of the Cornell faculty since 1989.
2. Prior to joining Cornell, I performed consumer product tests for the S.C. Johnson Wax company of Racine, Wisconsin. I also served as an internal consultant on product testing methods and as an expert on product fragrance issues such as masking of odors by air fresheners.
3. I received by Bachelor of Arts degree (cum laude) in Psychology from Yale University in 1974. I received my Sc.M. degree and Ph.D. in Experimental Psychology from Brown University in 1976 and 1978, respectively. I served as a National Research Council postdoctoral fellow at the U. S. Army Natick food laboratories from 1978 through 1980. I then performed research on taste and smell at the Monell Chemical Senses Center in Philadelphia for four years prior to joining Johnson Wax.
4. I have performed research on the chemical senses of taste and smell since my undergraduate years at Yale, publishing my first article in 1975. I have since published over 100 articles in the peer-reviewed literature and written over 150 additional works including book chapters, editorials and abstracts of over 100 presentations at professional society meetings. I am the co-author of the widely adopted textbook, *Sensory Evaluation of Foods*, which deals with sensory testing methods for foods and consumer products. A copy of my curriculum vitae including a list of publications is found in Appendix A.
5. I have been retained on behalf of plaintiffs in the matter of *City of New York v. Amerada Hess et al.* (MDL 1358, Southern District of New York). My time on this matter is billed at the rate of \$150 per hour for preparation of expert reports and opinions and \$300 per hour for testimony under oath. I am being paid for my time on this matter, not for my testimony.

**II. Summary of Opinions**

6. Based on the best study of odor detection of MTBE (methyl tertiary butyl ether), it is my opinion that MTBE can be detected by a significant proportion of the population by smell in drinking water at levels of 1-2 parts per billion (ppb). Based on the best study of odor detection of MTBE to date, this proportion is approximately 10%.
7. These are conservative values, however. In real-world conditions where people are exposed to MTBE in the water they drink, shower with, etc. on a

regular basis, it is more likely than not that the proportion of regular water users able to smell MTBE in the 1 – 2 ppb range is greater than 10%, and that some regular users will be able to detect MTBE at even lower levels.

### III. Discussion and Basis of Opinions

8. My opinions are based upon my review of the studies and documents listed herein, and my extensive education, training, research and experience in human taste and smell and sensory testing methods.
9. The level (concentration) at which an individual will detect an odor varies among the population. In order to measure this level, a group of people are tested using methods to estimate a detection threshold. The detection threshold is a statistically determined value that represents the minimum level detected by 50% of the test group. Thus some individuals are able to sense the test substance at lower levels, and some require higher levels than the threshold value to smell the substance. The threshold value is a useful number that can be used to compare the sensitivities of different individuals or groups. Thresholds are also convenient measures to compare the olfactory potency of various chemicals (a lower threshold means a more potent substance), a subject of great interest to olfactory physiologists and flavor chemists, for example. A threshold value does not however correspond to the level at which a significant but less than 50% proportion of the population (for example, 10% or 25%) can detect the compound of interest.
10. The detection threshold does not determine the level at which persons are likely to take on a distinctive taste or odor (i.e. be recognized), or the level at which consumers would find the substance objectionable.
11. Although my conclusions are based on studies of MTBE being smelled in the airspace above water samples, the conclusions apply as well to water which is ingested. When substances are ingested, volatile compounds can pass to the olfactory receptors via the nasopharynx, in the opposite route from sniffing through the external nares. This process is known as retronasal smell, but is commonly called "taste" by consumers. Thresholds for retronasally perceived odors are in the same general range as orthonasally perceived odors.
12. The value obtained for a detection threshold depends upon the details of the test procedure. Such details are discussed in my book, *Sensory Evaluation of Foods*, Chapter 6, Thresholds. Briefly, any variation of a method that makes the task more difficult for the person being tested, or that adds error variability to a procedure will result in a higher obtained value. An example of the former would be using a choice test in which the number of bottles containing the test solution were four and the number of bottles containing the water blank or control solution were also four and the subject would be required to sort them into two groups (a four-out-of-eight test, the so-called Harris-Kalmus procedure) as opposed to a test in which there was only one

test bottle and two controls (such as ASTM procedure E679). An example of the latter problem (adding a source of error variability) would be testing in a room with background odors, as opposed to an odor-free testing environment.

13. The most trustworthy estimate of the detection threshold for MTBE comes from a study directed by the firm of Malcolm Pirnie which subcontracted the data collection to the National Food Laboratories of Dublin, CA. This study has become known as the "Stocking study"<sup>1</sup> after the first author of the peer-reviewed report of the study.
14. The Stocking study employed a method known as ASTM E679<sup>2</sup> to measure the detectability of MTBE in the air space over water samples. This method is an industry consensus method that is peer reviewed every five years by ASTM Committee E-18. It is the method I recommend in my textbook and a method which I use as a laboratory exercise every year in my primary course at Cornell University.
15. Based on the results of the study known as Stocking et al., the best estimate of the human threshold for MTBE in the headspace above a water solution is 14 ppb<sup>3</sup> MTBE in the water solution itself. This value represents the interpolated level at a chance corrected<sup>4</sup> proportion of 50% of the population detecting<sup>5</sup>. The value agrees well with the ASTM method E679 calculation of the geometric mean of the individual best estimate thresholds at 15 ppb. The chance correction or correction for guessing applied here is the well-known Abbott's formula, which has been used since the 1920's in such diverse fields as educational testing and toxicology. It is more fully explained in footnote 4.
16. This data set also indicates that 10% of the population will detect MTBE at concentration levels of 1 – 2 ppb and 25% of the population at about 3 ppb<sup>6</sup>. These interpolated values are slightly more conservative but otherwise agree with the data set. For example, the ASTM method's individual best estimates show 10/57 (17.5%) of the test group reached their individual threshold estimates at 1.4 ppb. The fact that over 17% reached their individual threshold estimates at the lowest level tested indicates that some significant proportion of individuals may have sensitivity below that lowest tested concentration of 2 ppb. Had Stocking et al. extended the concentration series further in the lower direction we would have had a better estimate of these more sensitive individuals. In other words, the data are subject to a "floor effect" which renders the derived estimates in a conservative direction.
17. The 95% confidence interval around the 50% detection value is from 5 to 43 ppb. The 95% confidence interval around the 10% detection value is from 0.5 to 4 ppb and the 95% confidence interval around the 25% detection value is from 1.1 to 9.6 ppb.<sup>7</sup>
18. The Stocking study is considered the most trustworthy based on several factors including the following: a) it is the only study to use a reasonably large and diverse consumer group as the population sample, b) it uses a well-known threshold method based on industry consensus (ASTM E-679), c) the actual data set is presented in several publications and is available for

scrutiny and further analysis, d) the study was subcontracted to an independent testing laboratory with extensive experience in consumer testing and human sensory measurement, e) complete details of the procedure are available in the report by the Malcolm Pirnie group and the report's appendices, and f) test concentrations were confirmed by chemical analysis.

19. Other threshold values appear in the literature. The other published values are considered less trustworthy for the following reasons: a) use of small laboratory panels of unknown composition (often described as "expert" although the method by which such panels have been qualified or trained to be experts is not evident and for which the projection to the population at large is unjustified), b) use of nonstandard and/or out of date methods, c) use of methods that lack the forced-choice aspect, which are critically important in rendering the data a criterion-free measure from the perspective of signal detection theory (See Lawless, H. and Heymann, H. *Sensory Evaluation of Foods*, Chapter 5, and MacMillan, N.A. and Creelman, C.D., *Detection Theory: A User's Guide*, 1991). These other studies and threshold values will be discussed individually.
20. In the report by the firm of Malcom Pirnie dated June 26, 1998, the so-called Stocking Study data were re-analyzed by Andrew Berk, a professor of statistics at UCLA and a member of the advisory board for this study. The values for threshold arrived at by Professor Berk were considered when reviewing the literature and forming the basis for this opinion. However, they were discounted as unrealistic for several reasons. First, the value arrived at by Berk for 50% detection does not agree with the threshold level as determined by ASTM E-679, which by definition is the level at which approximately 50% of the population will detect the substance under the conditions of the study (the geometric mean lying close to the median or 50% cutoff in the sample distribution). Second, Berk's conclusion that the 50% detection level is at 40.62  $\mu\text{g/L}$  (ppb) or at 573  $\mu\text{g/L}$  (the former applying some kind of logistic regression and the latter using some kind of correction for chance) are inconsistent with the data which show that at 42  $\mu\text{g/L}$ , 77% of the sample had reached the ASTM individual threshold estimate. Furthermore a value of 573  $\mu\text{g/L}$  is beyond the concentration range of the study and flies in the face of common sense. The actual data show that 86% of the sample group had reached the criterion for an individual threshold estimate at the highest level tested (100 ppb). Finally, Berk himself notes in the "Follow-up Clarifying Comments" that he used an incorrect approximation in adjusting for chance guessing, by simply adding the chance level of .33 to the desired level (e.g. .50 probability of detection requires 83 percent correct). The nonsensical character of this approximation is clear when one considers that 80% detection when chance-adjusted by his method would require 113% correct choices, clearly impossible. The correct and well established adjustment for chance guessing is given by Abbott's formula (see footnote #4), which does not

correspond to Berk's oversimplification of simply adding .33 to the desired value. Such obvious mistakes make the data fitting process suspect as well. For these reasons, any conclusions of the Pirnie report that were based on the calculations of Berk are similarly discounted as unrealistic.

21. In the report known as Campden (2003)<sup>8</sup>, the procedure is purported to be a replication of that of Stocking et al. and found a threshold at 56.7 ppb. However, this study used a fully counterbalanced triangle procedure. On half the trials, two MTBE samples and one water blank were given ("six possible orders" implies all possible combinations). This is not what was done by The National Food Laboratory for the Stocking study (see appendices to Malcolm Pirnie report) which followed the ASTM protocol. The ASTM procedure dictates that the only combinations to be used are two water blanks and one test concentration (ASTM E-679, section 6.5 p. 38, vol 15.08 in the 2008 ASTM Book of Standards). Due to sensory adaptation, these additional combinations would result in a higher threshold estimate and much higher variability at the upper concentrations, which is evident in Campden 2003 Figure 1 (an obvious non-monotonic trend). Because the Campden estimate is based on an interpolated value from a line fit to the data, the estimate is further contaminated by the "noisy" values at the upper end of the series.
22. Another study<sup>9</sup> was conducted by the Campden group in 2004 which attempted to replicate an earlier study<sup>10</sup> (by the same group in 1993) using a small panel. No trend was found in the data that allowed the determination of a threshold for odor or for flavor, and so these data are moot.
23. The earlier (1993)<sup>10</sup> study by the Campden group found detection by "70% of an experienced panel" to be at a concentration level "between 0.04 and 0.06 ppb. This value is considered unreliable for several reasons including a) it is considerably lower by a factor of over 100 from that of Stocking and other studies, b) the data could not be replicated by the same research group, c) no confirmation of the actual test concentrations was performed using analytical chemistry, as noted by some other authors (e.g. Suffet) suggesting the possibility of a mistake in sample preparation. In addition the method suffers from some of the problems noted above including use of a small panel and lack of forced-choice.
24. In an early study by the firm of TRC Environmental Consultants<sup>11</sup> in 1981, a threshold value of 700 ppb was obtained. However the study suffers from several flaws including 1) use of a small panel of unknown composition, and more importantly 2) a floor effect in which the lowest tested concentration was already at threshold. Thus insufficient concentrations below the lowest level were tested, rendering this value unreliable.
25. A later report from TRC, dated April 29, 1993<sup>12</sup>, re-examined the threshold for MTBE in smelled and tasted solutions. Both studies suffer from the use of a small panel (N = 6) of laboratory personnel who might or might not be representative of the consuming public. Therefore these estimates are not considered trustworthy in generalizing to the level at which the public might detect MTBE. Furthermore, the taste trials were claimed to meet certain criteria including the use of a forced-choice procedure. However, panelists

- compared the test sample to a control sample and indicated if a flavor or aftertaste was detectable. This is not a forced choice procedure and allows the individual's subjective bias to report or not report a sensation creep into the picture, a violation of the principles of signal detection theory.
26. A study by Prah et al.<sup>13</sup> was conducted to evaluate the effects of exposure to MTBE and as part of this study the odor threshold was measured (at 180 ppb). Although this study included some water blanks to control for response bias, it also lacked the forced choice aspect of ASTM E-679 and thus was not truly bias-free. For this reason I do not consider the obtained value reliable.
  27. A study by Young et al. in 1996<sup>14</sup> found an MTBE odor threshold in the range of 34 ppb, but noted that three of the seven panelists could detect MTBE at 15 ppb. This study once again used a small panel that might or might not be representative of the consuming public. Also their task was a complicated one, which involved a pair of control samples, and a second pair of control plus test sample, with the criterion that the tester must identify the target as possessing an odor and also fail to identify an odor in the blank pair. This is a nonstandard method with no known precedent. For these reasons, I would not consider the study to be a reliable determination of the MTBE threshold.
  28. A presentation at the Water Quality Technology Conference of the AWWA in Nov. 1997<sup>15</sup> reported MTBE odor thresholds at a level of 24 to 37 ppb in odor free water and a slightly higher level in Colorado River water. However, this study suffered from several shortcomings. First, they used a triangle test that involved half the trials having two MTBE samples and one water blank. This is not the same as the 3-AFC method of ASTM E 679, which dictates that all trials will have two blanks and one test concentration. It is well known that the triangle procedure leads to poorer performance than the simple 3-AFC, due to the inherent variability of the triangle, the possibility of sensory adaptation to the additional MTBE sample (which would lower sensitivity). This would produce an artificially high estimate of the threshold value. See opinion 19 for a similar critique of the Campden 2003 study. Although the efforts of this group appear well motivated, their lack of expertise in sensory testing is evident in the title in which threshold determinations use the Flavor Profile Method (FP). The FP method is another procedure entirely and cannot be used for the purpose of determining thresholds.
  29. Two reports by Y. F Shen and colleagues<sup>16</sup> found MTBE thresholds in the range of 13.5 to 45.4 ppb. However, this study is considered unreliable for the following reasons: 1) use of a small panel, 2) lack of forced-choice methods, 3) no statistical backup for conclusions, and 4) many unusable data points in the tables shown, indicative of a flawed procedure.
  30. Studies such as Stocking et al. are obviously performed under laboratory conditions by individuals who are asked to focus their attention on the task at hand. Nonetheless they provide reasonable estimates of the levels at which consumers would perceive a smell in the real world. For example, flavor chemists routinely use threshold values to determine which flavor

compounds would be contributing the aroma of a natural product and which compounds (being below threshold) probably do not. In the case of the methodology employed in Stocking et al. the situation is similar to what would be experienced by a consumer smelling their drinking water from a glass or from a bottle.

31. However, several real-life factors may facilitate the detection of MTBE at levels below the values found by Stocking et al. It is well-known that obtained values decrease with repeated measurements on the same individuals<sup>17</sup>. This is relevant to the consumer evaluation of drinking water with MTBE in that they may have multiple opportunities to evaluate their water supply. The probability of detection at some point will simply increase as a function of the numbers of observations.
32. Other real-life scenarios might further facilitate the detection of MTBE. For example, when showering, the temperature of the water is higher than in drinking water, leading to increased partitioning of an odor substance into the air. The added surface area provided by droplets would also enhance the partitioning as compared with the same volume of water simply lying in a sink or tub.
33. Other factors in real life could mitigate against the detection of MTBE in some circumstances. For example, the presence of background odors in any environment would tend to mask or cover up an odor present in a water sample. Personal factors such as the age or sensitivity of the individual would also come into play. As a person ages, their sense of smell tends to decline, leaving them poorly protected against substances they should not breathe or ingest.

#### Footnotes.

1. See Stocking, A. J., Suffet, I.H., McGuire, M.J. and Kavanaugh, M.C. 2001. Implications of an MTBE odor study for setting drinking water standards. Journal AWWA, March 2001, pp. 95 – 105. Further details of the study including a complete description of the methodology are found in Technical Memorandum, Taste and Odor Properties of Methyl Tertiary-Butyl Ether and Implications for Setting a Secondary Maximum Contaminant Level. Prepared for the Oxygenated Fuels Association by Malcolm Pirnie, June 26, 1998.
2. See Designation E 679 – 04, Standard Practice for Determining Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Method of Limits, 2008 Annual Book of ASTM Standards, Vo.15.08, pp. 36 – 42. Briefly, the method involves the presentation of one test sample and two water blanks at each concentration level in an ascending series. The respondent must choose the sample that is different from the other two or guess if uncertain. Concentrations increase in a geometric progression such as factors of 2 (producing equal log steps). The data are analyzed as follows: Each individual's best estimate is taken as the geometric mean of the first concentration in which there is a correct choice and the concentration just

below it, given that all higher concentrations were chosen correctly. The threshold is then taken as the concentration which is the geometric mean of the individual best estimates.

3. The units, ppb (parts per billion) and  $\mu\text{g/L}$  (micrograms per liter), are considered equivalent for purposes of these opinions.
4. The chance correction is the standard formula wherein the corrected proportion = (observed proportion - chance probability)/(1 - chance probability). Using this formula, the chance corrected level of a true detection of 50% is 66.7% correct choices in a three alternative forced choice test such as the triangle procedure. The corresponding value for the 10% detection probability is 40% correct choice and for 25% detection is 50% correct choice. See Lawless, H. and Heymann, H. *Sensory Evaluation of Foods*, Chapter 6, Thresholds, p. 190, Eq. 6-4. See also MacMillan, N. A. and Creelman, C. D. *Detection Theory: A User's Guide*, p. 138, Eq. 5.18. See also ASTM Designation E-1432-04, *Standard Practice for Defining and Calculating Individual and Group Sensory Thresholds from Forced-choice Data Sets of Intermediate Size*, ASTM International Book of Standards, vol. 15.08 (2008) p. 86, Eq. 2. It is also known as Abbott's formula in toxicology, pharmacology and other disciplines and has been the standard formula for adjusting for baseline response since the 1920s. See Hoekstra, J.A. *Acute bioassays with control mortality*, *Water Air and Soil Pollution*, 35, 311 - 317 (1987), Eq. 3.
5. The interpolation on a dose-response curve for percent correct as a function of concentration is an alternative to the ASTM procedure of calculating the geometric mean, and usually agrees quite closely with that value. I teach this alternative analysis every year in my primary course at Cornell, *Sensory Evaluation of Foods*, in a laboratory exercise that uses the methods of ASTM E-679. See Lawless, H. and Heymann, H. *Sensory Evaluation of Foods*, Chapter 6, Thresholds. For an example of such interpolation on a dose response curve appearing in the peer-reviewed literature see Antinone, M. A., Lawless, H. T., Ledford, R. A. and Johnston, M. 1994. The importance of diacetyl as a flavor component in full fat cottage cheese. *Journal of Food Science*. 59, 38 - 42
6. These values were derived from a linear best fit (least squares) line to the percent correct plotted as a function of log of the concentration. Once the equation was derived, the log concentration was interpolated (at 66.6%, 50% and 40% correct responses) and then converted to the antilog to yield the concentration in ppb. The actual values were 14.1, 3.3 and 1.4 ppb, respectively. A logistic regression was also performed on the same data set and gave similar values (11.7, 3.5 and 1.8, respectively). As the linear fit had a higher R-squared value (.93 vs. .90), it was used as the basis for the opinion. It is important to note that the percent correct used in these calculations is the actual marginal proportion correct from the original data set (and not the derived values from the ASTM best-estimates of individual thresholds, which

- ignore correct performance before a reversal, i.e. correct choice followed by incorrect choice at a higher level. In order to make the correction for guessing properly, all the data must be considered and none ignored).
7. Confidence intervals (95% C.I.) were constructed by plotting upper and lower trendlines around the fitted curve, based on the standard error of the binomial proportions, and interpolating the log concentration values as in footnote 6.
  8. See Consumer Odour Threshold of Methyl Tertiary Butyl Ether (MTBE) in Water. Campden & Chorleywood Food Research Association Group, Report Issued 12<sup>th</sup> November 2003.
  9. The original report is Flavour and Odour Thresholds of Methyl Tertiary Butyl Ether (MTBE) in Water. Campden & Chorleywood Food Research Association Group, Report S/REP/74638. An extensive discussion of this report is also found in Suffet, I.H. A Re-evaluation of the taste and odour of methyl tertiary butyl ether (MTBE) in drinking water, in Water Science and Technology, 55(5) pp. 265 – 273 (2007) in which author Suffet reprints the graphs from the original report.
  10. Flavour and Odour Thresholds of Methyl Tertiary Butyl Ether (MTBE) in Water. Campden Food and Drink Research Association (CFDRA) reference S/140845/01, 1993.
  11. Letter from Alice D.Astle to Dr.Ralph Johnson of Shell Development Co. dated 5/20/81 and reference TRC Project No. 1674- M31. Another report was dated 5/14/08 in which lower concentrations were used and a larger panel size (N=23 vs. 10). However, the method did not force a choice ("Panelists sniffed each of the three bottles in the triad and picked out the bottle that was odorous, by number, *if they could.*") The phrase "if they could" indicates that a choice was not forced, which allows the individual's subjective bias to respond or not respond enter the picture. This is a violation of the principles of signal detection theory, as discussed above.
  12. Final Report to the ARCO Chemical Company on The Odor and Taste of Methyl Tertiary Butyl Ether (MTBE) and Ethyl Tertiary Butyl Ether (ETBE), april 29, 1993, authors K.M. Vetrano and S.S. Cha, TRC project 13442 – M31. This study appears to have been reprinted by the American Petroleum Institute the following year with data on an additional compound and in mixtures with gasoline (Odor Threshold Studies Performed with Gasoline and Gasoline combined with MTBE,, ETBE and TAME. Health and Environmental Sciences API Publication Number 4592, January 1994).
  13. Sensory, Symptomatic, Inflammatory, and Ocular Responses to and the Metabolism of Methyl Tertiary Butyl Ether in a Controlled Human Exposure Experiment. J. D.Prah et al.
  14. Taste and Odour Threshold Concentration of Potential Potable Water Contaminants. W. F. Young et al. Water Research 20 (2), 331 – 340 (1996).
  15. Taste and Odor Threshold Determinations Using the Flavor Profile Method. M. S. Dale et al. Presented at the Water Technology Conference, American Water Works Association, Denver, CO, Nov. 9 – 13, 1997.

16. Threshold Odor Concentrations of MTBE and Other Fuel Oxygenates. Y.F. Shen et al. and Effect of Residual Chlorine on the Threshold Odor Concentration of MTBE in Drinking Water, Y.F. Shen et al.
17. Effect of Practice and Instructions on Olfactory Threshold, Engen, T. E. Perceptual and Motor Skills, 10, 195 - 198 (1960). See also Determinants of Measured Olfactory Sensitivity, Rabin, M. D. and Cain, W. S. Perception & Psychophysics, 39, 281 - 286 (1986). See also Taste Perception with Age: Generic or Specific Losses in Threshold Sensitivity to the Five Basic Tastes. Molet, J., Christ-Hazelhof, e. and Heidema, J. Chemical Senses 26, 854 - 860 (2001).
18. Prescott, J. , Norris, L., Kunst, M. and Kim, S. 2005. Estimating a consumer rejection threshold for cork taint in white wine. Food Quality and Preference, 16, 345 - 349.

**CURRICULUM VITAE***updated 1/13/09*

**Harry T. Lawless, Professor**  
 106 Stocking Hall  
 Department of Food Science  
 New York State College of Agriculture and Life Sciences  
 Cornell University  
 Ithaca, NY 14853  
 PHONE: 255 - 7363  
 E-MAIL: [htl1@cornell.edu](mailto:htl1@cornell.edu)

**EDUCATION**

<u>Year</u>	<u>Degree</u>	<u>Institution</u>	<u>Field</u>
1978	Ph.D.	Brown University	Experimental Psychology
1976	M.Sc.	Brown University	Experimental Psychology
1974	B.A., <i>cum laude</i>	Yale University	Psychology

**PROFESSIONAL EXPERIENCE**

<u>Year</u>	<u>Experience</u>
1/89 – present	Professor, 1999 – present; Associate Professor, 1993 – 1998, Assistant Professor, 1989 – 1992, Department of Food Science, Cornell University. Member of the Graduate Fields of Food Science and Psychology. Director of Graduate Studies, Field of Food Science, 2001 – 2006.
7/84 - 12/88.	Senior Scientist, Product Evaluation Department, S. C. Johnson & Son,
1/81 - 6/84.	Assistant Member, Monell Chemical Senses Center.
6/80 - 12/80.	Visiting Scientist, General Foods Technical Center.
6/78 - 6/80.	Postdoctoral Associate, U. S. Army Natick Laboratory.

2001 CURRICULUM VITAE

**Professional Memberships (current)**

American Society for Testing and Materials (ASTM), E-18  
Association of Chemoreception Sciences  
Institute of Food Technologists (Professional Member)  
Sensory Evaluation Division Chair, 1991 – 1992.  
Society of Sensory Professionals, Founding Sponsor  
American Water Works Association.

**Editorial Boards (current)**

Journal of Sensory Studies, Associate Editor  
Food Quality and Preference  
Chemosensory Perception  
Reviewer for Chemical Senses, Journal of Agricultural and Food Chemistry, Journal of  
Texture Studies, Food Quality, Journal of Sensory Studies, Food Quality and Preference,  
Chemosensory Perception.

**Honors and Awards**

Yale B.A. *cum laude*, 1974.  
Sigma Xi, 1978.  
Fulbright Research Award, Finland, 1995  
William Evans Visiting Fellow, University of Otago, 1995  
Teaching Excellence Award, Dept. Food Science, Cornell, 2006

2001 CURRICULUM VITAE

ACADEMIC RECORD

TEACHING

Administrative Leadership:  
Director of Graduate Studies (Field of Food Science, 2001 - 2006)

- Courses Currently Taught  
FS4100 Sensory Evaluation of Foods,  
FS 4560 Advanced Concepts in Sensory Evaluation  
FS 6160 Flavors, Analysis and Applications  
Guest lecturer in FS 1010, Introductory Food Science, FS 4300 Understanding Wines

Undergraduate students mentored: 2 – 3 per year since 1990, for independent study projects and the Food Science Summer Scholars Program.

GRADUATE STUDENTS

- Current : Michael Nestrud, Ph.D., Scott McClure, M.S.
- Completed as Committee Chair
  - Master of Science: 26
  - Doctor of Philosophy: 4
  - Master or Professional Studies: 1

Committee memberships (Minor member)

- Current : Ghokan Boran (Ph.D) Food Science, Justin Jack Scheiner (Ph.D.)  
Enology, Bryson Bolton, (MS) Food Science.
- Completed
  - Master of Science: 12
  - Doctor of Philosophy: 8
  - Master or Professional Studies: 3

External committees/exams/readerships:

Kevin Blot, Psychology Ph.D. Clark University, 2003. Minor committee member

Sanna-Maija Meittinen, Food Technology, Ph.D. Univ. Helsinki. 2004. Examiner.

Postdoctoral Associates

1991-1992 Nalini Ayya  
1993-94 Raginild Solheim  
1997-98 Professor Myung-Suk Oh (sabbatic)  
1999 Professor Richard Mason (sabbatic)

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OTHER PROFESSIONAL ACTIVITIES

**Recent Committees/Service:**

CALS/University: Ad-hoc committee for promotion to full professor (2002)  
Alternate Senator, University Senate, College of Agriculture Senate (2008 – present)

**Department Committees:**

Director of Graduate Studies, 2001 – 2006.  
Admissions committee, Field of Food Science, 1998 - 2006. Emergency substitute, 2007.  
Assistantship committee: 2001 – 2006  
Awards Committee: 2002 – 2006

**External committees:**

Finnish National Academy of Sciences, Nutrition and Food Science review panel, 2006.  
Dissertation committee, Kevin Blot, Ph.D. candidate, Hiatt School of Psychology, Clark University, Worcester, MA (2002)  
Scientific Program Committee; Fifth Pangborn Symposium on Sensory Science, Dijon, France, 2001; Sixth Pangborn Symposium on Sensory Science, Boston, MA June 2003;  
Seventh Pangborn Symposium on Sensory Science, Minneapolis, MN, July 2006.  
Program Committee, Society of Sensory Professionals, First Annual Meeting, November, 2008.  
Scientific Program Committee; Eighth Pangborn Symposium on Sensory Science, Florence, Italy, July 2009.

**Recent Conferences Attended:**

Sixth Pangborn Symposium on Sensory Science (3 presentations/abstracts) August 2007.  
Association for Chemoreception Sciences, Annual Meeting, (3 presentations/abstracts). April 2007.  
Sensometrics Annual Meeting, Brock Univ. Ontario, July 2008 (2 presentations/abstracts)  
Society of Sensory Professionals, Cincinnati, OH, Nov. 2008 (2 presentations/abstracts).

**Recent invited presentations**

"Adventures in Military Ration Acceptance Testing: My Life with Uncle Sam". Presentation to the Food Science and Technology Department, NY State Agricultural Experiment Station, Geneva, NY 1/23/08.  
Sigma Xi lecture, U. S. Army Natick Labs, "Beyond the four basic tastes" August 18, 2006.  
Advanced Sensory Evaluation Workshop, Paris, France, July 18 – 20, 2006.  
Food Science Department, Virginia Polytechnic and State University, Blacksburg, VA  
"Sensory modalities of metallic taste." 4/26/05.

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**EXTENSION/OUTREACH**

In alternate years I give workshops to food industry professionals concerning sensory evaluation methods and statistical analysis of sensory data. In 2007 we presented an intermediate sensory methods in June, with 11 attendees. I also field about 1 – 2 inquiries per month (via email or phone) about sensory evaluation methods from workers in the foods and consumer products industries. My Cornell extension appointment effort percentage is 5%.

**CONSULTING**

Consultant to various food companies on flavor, texture and sensory evaluation test methods.

Consultant (expert witness) in patent litigation, flavors.

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PUBLICATIONS

Publications in peer-reviewed journals (104, reverse chronological):

Recent:

Epke, E., McClure, S. T. and Lawless, H. T. 2008. Effects of nasal occlusion and oral contact on perception of metallic taste from metal salts. *Food Quality and Preference*, 20, 133 – 137.

Stevens, D.A., Baker, D., Cutroni, E., Frey, A., Pugh, D. and Lawless, H. T. 2008. A direct comparison of the taste of electrical and chemical stimuli. *Chemical Senses*, 33, 405 – 413.

Olabi, A. and Lawless, H.T. 2008. Persistence of context effects with training and reference standards. *Journal of Food Science*, 73, S185 – S189.

Nestrud, M. and Lawless, H. T. Perceptual mapping of citrus juices using nappe and profiling data from culinary professionals and consumers. *Food Quality and Preference*, 19, 431 – 438.

Cardello, A., Lawless, H. T. and Schutz, H. G. 2008. Effects of extreme end anchors and interior label spacing on labeled affective magnitude scales. *Food Quality and Preference*, 19, 473 - 480.

Epke, E. M. and Harry T. Lawless, H. T. 2007 Retronasal smell and detection thresholds of iron, copper and sodium salts. *Physiology and Behavior*, 92, 487 – 491.

McClure, S. T. and Lawless, H. T. 2007. A comparison of two electric taste stimulation devices, metallic taste responses and lateralization of taste. *Physiology and Behavior*, 92, 658 - 664.

Pre – 2007

Chapman, K. W. and Lawless, H. T. 2006. Expectations and stability of preference choice. *Journal of Sensory Studies*, 21, 441 – 455.

Lim, J. and Lawless, H. T. 2006. Detection thresholds and taste qualities of iron salts. *Food Quality and Preference*, 17, 513 – 521.

Stevens, D. A., Smith, R. F. and Lawless, H. T. 2006. Multidimensional scaling of ferrous sulfate and basic tastes. *Physiology and Behavior*, 87, 272 - 279.

Yang, H. and Lawless, H. T. 2006. Time-intensity characteristics of iron compounds. *Food Quality and Preference*, 17, 227 - 343.

Lim, J. and Lawless, H. T. 2005. Qualitative differences of divalent salts: Multidimensional scaling and cluster analysis. *Chemical Senses*, 30, 719 – 726.

2001 CURRICULUM VITAE

- Lubran, M. B., Lawless, H. T., Lavin, E. And Acree, T. E. 2005. Identification of metallic-smelling 1 octen-3-one and 1-nonen-3-one from solutions of ferrous sulfate. *Journal of Agricultural and Food Chemistry*, 53, 8325 - 8327.
- Chapman, K. W. and Lawless, H. T. 2005. Sources of error and the no preference option in dairy product testing. *Journal of Sensory Studies*, 20, 454 - 468.
- Lawless, H. 2005. Commentary: Every Tool has its proper use. *Journal of Sensory Studies*, 20, 380 - 388.
- Lim, J. and Lawless, H. T. 2005. Oral sensations from iron and copper sulfate *Physiology and Behavior*, 85, 308 - 313.
- Yang, H. H. and Lawless, H. T. 2005. Descriptive analysis of divalent salts. *Journal of Sensory Studies*, 20, 97 - 113.
- Lawless, H. T., Stevens, D. A., Chapman, K. W. and Kurtz, A. 2005. Metallic taste from ferrous sulfate and from electrical stimulation. *Chemical Senses*, 30, 185 - 194.
- Lawless, H. T., Schlake, S., Smythe, J., Lim, J., Yang, H., Chapman, K. and Bolton, B. 2004. Metallic taste and retronasal smell. *Chemical Senses* 29, 25-33.
- Pelletier, C. P., Lawless, H. T. and Horne, J. 2004. Sweet-sour mixture suppression in older adults. *Food Quality and Preference*, 15, 105 - 116.
- Pelletier, C. P. and Lawless, H. T. 2003. Effect of citric acid and citric-acid sucrose mixtures on swallowing in neurogenic oropharyngeal dysphagia. *Dysphagia*, 18, 231 - 241.
- Lawless, H. T., Rapacki, F., Horne, J., Hayes, A. and Wang, G. 2003. The taste of calcium salts in mixtures with NaCl, sucrose and citric acid. *Food Quality and Preference*, 15, 83 - 89.
- Lawless, H. T., Bender, S., Oman, C. and Pelletier, C. 2003. Gender, age, vessel size, cup vs. straw sipping and sequence effects on sip volume. *Dysphagia*, 18, 196 - 202.
- Pelletier, C. P. and Lawless, H. T. 2003. Measuring taste acceptance in neurologically impaired adults. *Food Quality and Preference*, 14, 595 - 602.
- Lawless, H. T., Rapacki, F., Horne, J. and Hayes, A. 2003. The taste of calcium and magnesium salts and anionic modifications. *Food Quality and Preference*, 14, 319 - 325.
- Horne, J., Hayes, J. and Lawless, H. T. 2002. Turbidity as a measure of salivary protein reactions with astringent substances. *Chemical Senses*, 27, 653 - 659.
- Olabi, A., Lawless, H. T., Hunter, J. B., Levitsky, D. A. and Halpern, B.P. 2002. The Effect of Microgravity and Space Flight on the Chemical Senses, *Journal of Food Science*, 76, 468 - 478.

2001 CURRICULUM VITAE

Horne, J. H., Lawless, H. T., Speirs, W. and Sposato, D. 2002. Bitter taste of saccharin and acesulfame-K. *Chemical Senses*, 27, 31-38.

Horne, J. Olabi, A., Greenwalt and Lawless, H. T. 2001. Visual haze detection threshold assessment by ascending method of limits and a transformed staircase procedure in apple juice simulations under "store like" conditions. *Journal of Sensory Studies*, 17, 1.

Diamond, J. and Lawless, H. T. 2001. Context effects and reference standards with magnitude estimation and the labeled magnitude scale. *Journal of Sensory Studies* 16, 1 - 10.

Chapman, K. W., Lawless, H. T. and Boor, K. J. 2001. Quantitative descriptive analysis and principal component analysis for sensory characterization of ultrapasteurized milk. *Journal of Dairy Science*, 84, 12 - 20.

Lawless, H. T., Hartono, C. and Hernandez, S. 2000. Thresholds and suprathreshold intensity functions for capsaicin in oil and aqueous based carriers. *Journal of Sensory Studies*, 15, 437 - 447.

Lawless, H. T., Horne, J. and Speirs, W. 2000. Contrast and range effects for category, magnitude and labeled magnitude scales. *Chemical Senses*, 25, 85-92.

Lawless, H. T. 1999. Descriptive Analysis of Complex Odors: Reality, Model or Illusion? *Food Quality and Preference*, 10, 325 - 332.

Hotchkiss, J. H., Chen, J. H. and Lawless. 1999. Combined effects of carbon dioxide addition and barrier films on microbial and sensory changes in pasteurized milk. *Journal of Dairy Science*, 82, 690 - 695.

Hernandez, S. V. and Lawless, H. T. 1999. A method of adjustment for preference levels of capsaicin in liquid and solid food systems among panelists of two ethnic groups. *Food Quality and Preference* 10, 41 - 49.

Huang, Y.-T. and Lawless, H. T. 1998. Sensitivity of the ABX discrimination test. *Journal of Sensory Studies*, 13, 229 - 239.

Lavin, J. and Lawless, H. T. 1998. Effects of color and odor on judgments of sweetness among children and adults. *Food Quality and Preference*, 9, 283 - 289.

Lawless, H. T. 1998. Theoretical Note: Tests of synergy in sweetener mixtures. *Chemical Senses*, 23, 447 - 451.

Lawless, H. T., Liu, Y.-F. and Goldwyn, C. 1997. Evaluation of wine quality using a small panel hedonic scaling method. *Journal of Sensory Studies*, 12, 317 - 332.

2001 CURRICULUM VITAE

Lawless, H. T., Vanne, M. and Tuorila, H. 1997. Categorization of English and Finnish texture terms among consumers and food professionals. *Journal of Texture Studies* 28, 687 - 708.

Kähkönen, P., Tuorila, H. and Lawless, H. 1997. Lack of effect of taste and nutrition claims on sensory and hedonic responses to a fat free yogurt. *Food Quality and Preference*, 8, 125 - 130.

Lawless, H. T., Home, J and Giasi, P. 1996. Astringency of organic acids is related to pH. *Chemical Senses*, 21, 397 - 403.

Lawless, H. T., Tuorila, H., Jouppila, K., Virtanen, P. and Home, J. 1996. Effects of guar gum and microcrystalline cellulose on sensory and thermal properties of a high fat model food system. *Journal of Texture Studies*, 27, 493 - 516.

Solheim, R. and Lawless, H. T. 1996. Consumer purchase probability affected by attitude towards lowfat foods, liking, private body consciousness and information on fat and price. *Food Quality and Preference*, 7, 137 - 143.

Thomas, C. J. C. and Lawless, H. T. 1995. Astringent subqualities in acids. *Chemical Senses*, 20, 593 - 600.

Phillips, L.G., McGiff, M.L., Barbano, D. M. And Lawless, H. T. 1995. The influence of nonfat dry milk on the sensory properties, viscosity and color of lowfat milks. *Journal of Dairy Science*, 78, 2113 - 2118.

Lawless, H. T., Sheng, N. and Knoop, S. S. C. P. 1995. Multidimensional scaling of sorting data applied to specialty cheeses. *Food Quality and Preference*, 6, 91 - 98.

Lawless, H. T. 1995. Dimensions of Quality: A Critique. *Food Quality and Preference*, 6, 191 - 196.

Miller, D. K., Smith, V. L., Kanner, J., Miller, D. D. and Lawless, H. T. 1995. Lipid oxidation and warmed-over aroma (WOA) in cooked ground pork from swine fed increasing levels of iron. *Journal of Food Science*, 59, 751 - 756.

Phillips, L. G., McGiff, M. L., Barbano, D. M. and Lawless, H. T. 1995. The influence of fat on the sensory properties, viscosity and color of low-fat milks. *Journal of Dairy Science*, 78, 1258 - 1266.

Lawless, H. T., Corrigan Thomas, C. C. and Johnston, M. 1995. Variation in odor thresholds for L-carvone and cineole and correlations with suprathreshold intensity ratings. *Chemical Senses*, 20, 9 - 17.

Clark, C. C. and Lawless, H. T. 1994. Limiting response alternatives in time-intensity scaling: An examination of the Halo-Dumping effect. *Chemical Senses*, 19, 583 - 594.

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- Lawless, H. T. 1994. Getting results you can trust from sensory evaluation. *Cereal Foods World*, 39 (11), 809 - 814.
- Lawless, H. T., Corrigan, C. L. and Lee, C. B. 1994. Interactions of astringent substances. *Chemical Senses*, 19, 141 - 154.
- Antinone, M. A., Lawless, H. T., Ledford, R. A. and Johnston, M. 1994. The importance of diacetyl as a flavor component in full fat cottage cheese. *Journal of Food Science*, 59, 38 - 42.
- Lawless, H. T., Antinone, M. J., Ledford, R. A. and Johnston, M. 1994. Olfactory responsiveness to diacetyl. *Journal of Sensory Studies*, 9, 47 - 56.
- Lawless, H. T. 1993. The education and training of sensory scientists. *Food Quality and Preference* 4, 51 - 63.
- Stoer, N. and Lawless, H. T. 1993. A comparison of single product scaling and relative to reference scaling in sensory evaluation of dairy products. *Journal of Sensory Studies*, 8,
- Bertino, M. and Lawless, H. T. 1993. Understanding mouthfeel attributes: A multidimensional scaling approach. *Journal of Sensory Studies*, 8, 101 - 114.
- Lawless, H. T., Torres, V. and Figueroa, E. 1993. Sensory evaluation of hearts of palm. *Journal of Food Science*, 58, 134 - 137.
- Lawless, H. T. and Claassen, M. R. 1993. Validity of descriptive and defect-oriented terminology systems for sensory analysis of fluid milk. *Journal of Food Science*, 58, 108 - 112, 119.
- Ayya, N. and Lawless, H. T. 1992. Qualitative and quantitative evaluation of high-intensity sweeteners and sweetener mixtures. *Chemical Senses*, 17, 245 - 259.
- Claassen, M. and Lawless, H. T. 1992. Comparison of descriptive terminology systems for sensory evaluation of fluid milk. *Journal of Food Science*, 57, 596 - 600, 621.
- Williamson, D. M., Gravani, R. B. and Lawless, H. T. 1992. Correlating food safety knowledge with home food preparation practices. *Food Technology*, 48(5), 94, 96, 98, 100.
- Lawless, H. T., Glatter, S. and Hohn, C. 1991. Context dependent changes in the perception of odor quality. *Chemical Senses*, 16, 349 - 360.
- Lee, C. B. and Lawless, H. T. 1991. Time-course of astringent materials. *Chemical Senses*, 16, 225 - 238.
- Lawless, H. T. and Glatter, S. 1991. Consistency of multidimensional scaling models derived from odor sorting. *Journal of Sensory Studies*, 5, 217 - 230.

2001 CURRICULUM VITAE

- Lawless, H. T. 1991. The importance of smell in food quality and sensory evaluation. *Journal of Food Quality*, 14, 33 - 60.
- Lawless, H. T. 1989. Pepper potency and the forgotten flavor sense. *Food Technology*, 43 (11), 52 - 58.
- Lawless, H. T. 1989. Logarithmic transformation of magnitude estimation data and comparisons of scaling methods. *Journal of Sensory Studies*, 4, 75 - 86.
- Lawless, H. T. 1989. Exploration of fragrance categories and ambiguous odors using multidimensional scaling and cluster analysis. *Chemical Senses*, 14, 349 - 360.
- Lawless, H. T. and Klein, B. P. 1989. Academic vs. industrial perspectives on sensory evaluation. *Journal of Sensory Studies*, 3, 205 - 216.
- Lawless, H. T. 1989. Understanding wine flavor. CAREF Research Reports, 5, 1 - 4.
- Lawless, H. T. and Stevens, D. A. 1988. Responses by humans to oral chemical irritants as a function of locus of stimulation. *Perception & Psychophysics*, 43, 72 - 78.
- Stevens, D. A. and Lawless, H. T. 1987. Enhancement of responses to sequential presentation of oral chemical irritants. *Physiology and Behavior*, 39, 63 - 65.
- Lawless, H. T. 1986. Sensory interactions in mixtures. *Journal of Sensory Studies*, 1, 259 - 274.
- Civille, G. V. and Lawless, H. T. 1986. The importance of language in describing perceptions. *Journal of Sensory Studies*, 1, 203 - 215.
- Stevens, D. A. and Lawless, H. T. 1986. Putting out the fire: Effects of tastants on oral chemical irritation. *Perception & Psychophysics*, 39, 346 - 350.
- Lawless, H. T. and Malone, G. J. 1986. A comparison of scaling methods: Sensitivity, replicates and relative measurement. *Journal of Sensory Studies*, 1, 155 - 174.
- Lawless, H. T. and Malone, J. G. 1986. The discriminative efficiency of common scaling methods. *Journal of Sensory Studies*, 1, 85 - 96.
- Lawless, H. T., Rozin, P. and Shenker, J. 1985. Effects of oral capsaicin on gustatory, olfactory and irritant sensations and flavor identification in humans who regularly or rarely consumer chili pepper. *Chemical Senses*, 10, 579 - 589.
- Mattes, R. D. and Lawless, H. T. 1985. An adjustment error in optimization of taste intensity. *Appetite*, 6, 103 - 114.
- Lawless, H. T. 1985. Sensory development in children: Research in taste and olfaction. *Journal of the American Dietetic Association*, 85, 557 - 585.

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- Lawless, H. T. 1984. Oral chemical irritation: Psychophysical properties. *Chemical Senses*, 9, 143 - 155.
- Lawless, H. T. and Stevens, D. A. 1984. Effects of oral chemical irritation on taste. *Physiology and Behavior*, 32, 995 - 998.
- Curtis, D. W., Stevens, D. A. and Lawless, H. T. 1984. Perceived intensity of the taste of sugar mixtures and acid mixtures. *Chemical Senses*, 9, 107 - 120.
- Lawless, H. T. 1984. Flavor description of white wine by "expert" and non-expert wine consumers. *Journal of Food Science*, 49, 120 - 123.
- Lawless, H. T. and Schlegel, M. P. 1984. Direct and indirect scaling of taste - odor mixtures. *Journal of Food Science*, 49, 44 - 46.
- Lawless, H. T. and Zwillenberg, D. 1983. Clinical methods for testing taste and olfaction. *Transactions of the Pennsylvania Academy of Ophthalmology and Otolaryngology*, Fall, 1983, 190 - 196.
- Lawless, H. T. 1983. Contextual effects in category ratings. *Journal of Testing and Evaluation*, 11, 346 - 349.
- Lawless, H. T., Hammer, L. and Corina, M. 1983. Aversive reactions to bitter substances among children with and without histories of accidental ingestion. *Journal of Toxicology: Clinical Toxicology*, 19, 951 - 954.
- Lawless, H. T. and Stevens, D. A. 1983. Cross-adaptation of sucrose and intensive sweeteners. *Chemical Senses*, 7, 309 - 315.
- Lawless, H. T. 1982. Adapting efficiency of salt-sucrose mixtures. *Perception & Psychophysics*, 32, 419 - 422.
- Lawless, H. T. 1982. Paradoxical adaptation to taste mixtures. *Physiology and Behavior*, 29, 149 - 152.
- Stevens, D. A. and Lawless, H. T. 1981. Age-related changes in flavor perception. *Appetite*, 2, 127 - 136.
- Lawless, H. T. 1980. A comparison of different methods for assessing sensitivity to the taste of phenylthiocarbamide (PTC). *Chemical Senses*, 5, 247 - 256.
- Lawless, H. T. 1979. The taste of creatine and creatinine. *Chemical Senses*, 4, 249 - 252.
- Lawless, H. T. 1979. Evidence for neural inhibition in bittersweet taste mixtures. *Journal of Comparative and Physiological Psychology*, 93, 538 - 547.

2001 CURRICULUM VITAE

- Lawless, H. T. and Skinner, E. Z. 1979. The duration and perceived intensity of sucrose taste. *Perception & Psychophysics*, 25, 249 - 258.
- Lawless, H. T. 1978. Recognition of common odors, pictures and simple shapes. *Perception & Psychophysics*, 24, 493 - 495.
- Lawless, H. T. 1977. The pleasantness of mixtures in taste and olfaction. *Sensory Processes*, 1, 227 - 237.
- Lawless, H. T. and Engen, T. 1977. Associations to odors: Interference, mnemonics and verbal labeling. *Journal of Experimental Psychology: Human Learning and Memory*, 3, 52 - 57.
- Lawless, H. T. and Cain, W. S. 1975. Recognition memory for odors. *Chemical Senses and Flavor*, 1, 331 - 337.

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## Abstracts of papers presented at professional meetings

### 2008:

Cardello, A. V., Lawless, H. T. and Schutz, H. G. End anchor and label spacing effects in labeled magnitude scales of affect. 2008 Meeting, Eastern Psychological Association.

Lawless, H. T. and Nestrud, M. A. A comparison of sorting and nappe analysis by multidimensional scaling and multifactor analysis. First Annual Meeting of the Society of Sensory Professionals, Cincinnati, OH. Nov. 5 - 7, 2008.

McClure, S. T. and Lawless, H. T. Examination of the subject-defined 2 - AFC. First Annual Meeting of the Society of Sensory Professionals, Cincinnati, OH. Nov. 5 - 7, 2008.

Nestrud, M. A. and Lawless, H. T. Perceptual mapping of apples and cheeses using projective mapping and sorting. First Annual Meeting of the Society of Sensory Professionals, Cincinnati, OH. Nov. 5 - 7, 2008.

Lawless, H. T. and Nestrud, M. A. Discovering missing dimensions: A comparison of sorting and nappe analyses by multidimensional scaling and multifactor analysis. Eleventh Sensometrics meeting, Brock University, Ontario, July 20 - 23, 2008.

Nestrud, M. A., McClure, S. and Lawless, H. T. The distribution of the Rv statistic for comparing multivariate configurations. Eleventh Sensometrics meeting, Brock University, Ontario, July 20 - 23, 2008.

Kurtz, A.J., Lawless, H. T., Acree, T.E. (2008). Odorant Mixture Gestalt, The 12th International Weurman Flavour Research Symposium, Interlaken Switzerland, June 30-July 4th.

Kurtz, A.J., Lawless, H.T., Acree, T.E. (2008) Cross-Adaptation of Green Odors with OR-I& Agonists, ISOT XV: AChemS International Symposiums on Olfaction and Taste, July 21-26.

### 2007:

Stevens, D. A., Baker, D. Pugh, D. and Lawless, H. T. 2007. Comparison of anodal and cathodal electrical taste, Association for Chemoreception Sciences, Annual Meeting, Sarasota, FL, 4/25/07.

Eppke, E. M. and Lawless, H. T. 2007. Detection thresholds of iron, copper and sodium compounds with and without nasal occlusion. Association for Chemoreception Sciences, Annual Meeting, Sarasota, FL, 4/26/07.

Lawless, H. T. 2007 Bayesian analysis in sensory testing. Pangborn Symposium on Sensory Science, Minneapolis, MN 8/16/07.

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Nestrud, M. A. and Lawless, H. T. 2007. Methods of analysis of nappe map technique and a comparison of citrus juice preference. Pangborn Symposium on Sensory Science, Minneapolis, MN 8/13/07.

Stevens, D.A., Cutroni, E.R., Frey, A.M., Lawless, H.T. 2007. Comparison of anodal and cathodal electric taste, ferrous sulfate and basic taste solutions. Pangborn Symposium on Sensory Science, Minneapolis, MN 8/14/07.

Yu, K. C. ,Lawless, H. T. 2007. Detection and identification of metallic odorants in a model solution of ferrous sulfate and linoleic acid. Association for Chemoreception Sciences, Annual Meeting, Sarasota, FL, 4/26/07.

Pre-2007

1. Lawless, H. T. Evidence for neural inhibition in bittersweet taste mixtures. Association for Chemoreception Sciences, Sarasota, FL 4/25/79.
2. Lawless, H. T. Classification of PTC tasters and nontasters by a category scaling task. The Psychonomic Society, Phoenix, AZ 11/10/79.
3. Stevens, D. A. and Lawless, H. T. Age-related changes in flavor perception. Association for Chemoreception Sciences, Sarasota, FL 5/5/80.
4. Lawless, H. T. Misadventures in physiologizing: adaptation and taste mixology. Association for Chemoreception Sciences, Sarasota, FL 4/18/82.
5. Lawless, H. T. , Hammer, L. and Corina, M. Bitterness as a deterrent to accidental ingestion. Association for Chemoreception Sciences, Sarasota, FL 4/18/82.
6. Lawless, H. T. and Civille, G. V. Context effects in categorical judgment. ASTM Committee E-18 on Sensory Evaluation of Materials and Products. Quebec City, Quebec. 5/20/82. *(invited)*
7. Lawless, H. T. and Stevens, D. A. Cross adaptation and intensive sweeteners. Eastern Psychological Association, Philadelphia, PA. 4/8/83.
8. Lawless, H. T. and Zwillinberg, D. Clinical methods for testing taste and olfaction. Pennsylvania Academy of Ophthalmology and Otolaryngology, Hershey, PA 5/27/83.
9. Kare, M. R. and Lawless, H. T. Age-related changes in taste and olfaction. Symposium on clinical geriatric dentistry: Biomedical and Psychosocial Aspects, Chicago, IL 6/1/83.

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10. Lawless, H. T. Multidimensional scaling. Conference on human taste and smell: Measurements and uses. Memorial Sloan-Kettering Cancer Center, New York, NY. 6/2/83. *(invited)*
11. Lawless, H. T. and Schlegel, M. P. Direct vs. indirect scaling of taste odor-mixtures. Institute of Food Technologists, New Orleans, LA. 6/21/83.
12. Curtis, D. W., Stevens, D. A. and Lawless, H. T. Perceived intensity of the taste of sugar mixtures and acid mixtures. Institute of Food Technologists, New Orleans, LA. 6/21/83.
13. Lawless, H. T. Sensory development in children: Research in taste and olfaction. American Dietetic Association, Anaheim, CA. 6/21/83. *(invited)*
14. Lawless, H. T. Psychological perspectives on winetasting and the recognition of volatile flavors. Symposium on Alcoholic Beverages, University of Reading, Reading, U.K. 3/28/84. *(invited)*
15. Lawless, H. T. and Gillette, M. How hot is hot? Sensory responses to oral chemical heat. American Chemical Society, Division of Agricultural and Food Chemistry, Philadelphia, PA. 8/28/84. *(invited)*
16. Stevens, D. A. and Lawless, H. T. Effects of tastants on oral irritation produced by capsaicin and piperine. Association for Chemoreception Sciences, Sarasota, FL. 4/27/85.
17. Lawless, H. T. Sensory interactions in mixtures. Institute of Food Technologists, Dallas, TX. 6/18/86. Synopsis published in Food Technology, 1986, 40(1), 67. *(invited)*
18. Civile, G. V. and Lawless, H. T. The importance of language in describing perceptions. Institute of Food Technologists, Dallas, TX. 6/18/86. Synopsis published in Food Technology, 1986, 40(1), 67. *(invited)*
19. Stevens, D. A. and Lawless, H. T. Sequential interactions of oral chemical irritants. Association for Chemoreception Sciences and International Society for Olfaction and Taste. Snowmass, CO. 7/21/86. Chemical Senses, 1986, 11, 668.
20. Stevens, D. A. and Lawless, H. T. Effects of locus of stimulation on human responses to oral chemical irritants. The Psychonomic Society, New Orleans, LA. 11/13/86.
21. Lawless, H. T. and Stevens, D. A. Mixtures of oral chemical irritants. International Symposium on Perception of Complex Mixtures in Odor and Taste. Sarasota, FL. 4/28/87. *(invited)*
22. Lawless, H. T. An analogy to the release from suppression effect occurs in odor mixtures. Association for Chemoreception Sciences, Sarasota, FL 5/2/87. Chemical Senses, 1987, 12, 674.

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23. Lawless, H. T. Odour description and odour classification revisited. Symposium on Food Acceptability, to honor the retirement of Prof. Roland Harper. University of Reading, Reading, U. K. 9/15/87.
24. Lawless, H. T. and Stevens, D. A. Recent psychological studies in the chemical senses. ASTM Committee E-18 on Sensory Evaluation of Materials and Products. Ft. Lauderdale, FL 11/19/87. (invited)
25. Lawless, H. T. Categorization of ambiguous odors in restricted and unrestricted classification tasks with multidimensional scaling analysis. Association for Chemoreception Sciences, Sarasota, FL. 4/30/88. Chemical Senses, 1988, 13, 706.
26. Lawless, H. T. and Stevens, D. A. Differences between and interactions of oral chemical irritants: Neurophysiological and perceptual implications. International Symposium on Chemical Irritation in the Nose and Mouth. Monell Chemical Senses Center, Philadelphia, PA. 6/10/88. (invited)
27. Lawless, H. T. and Klein, B. P. Academic vs. Industrial Perspectives on Sensory Evaluation. Institute of Food Technologists, New Orleans, LA 6/19/88. (invited)
28. Lawless, H. T. Context-dependent shifts in odor quality. The Psychonomic Society, Chicago, IL. 11/11/88.
29. Lawless, H. T. Considerations in Sensory-Instrumental Relationships. Symposium on Flavor Chemistry and the Senses (to honor the retirement of Professor Emeritus W. Frank Shipe), Ithaca, NY. 4/3/89. (invited)
30. Lawless, H. T. Logarithmic transformation of magnitude estimation data and comparisons of scaling methods. Given at the Association for Chemoreception Sciences, Eleventh Annual Meeting, Sarasota, FL, 5/15/89. Chemical Senses, 1989, 14.
31. Lawless, H. T. and Acree, T. E. Computers in sensory analysis. Given at Ag. & Food Chem. Division of American Chemical Society, Fall Meeting, Miami, FL, 9/14/89 (invited)
32. Lawless, H. T. The importance of smell in food quality and sensory evaluation. Southern Association of Agricultural Scientists, Symposium on Food Quality and the Senses, Little Rock, AK, 2/5/90. (invited)
33. Lawless, H. T., Lee, C. B. and Tucciarone, R. A. Qualitative and quantitative perceptual attributes of astringent substances. Given at the Association for Chemoreception Sciences, Twelfth Annual Meeting, Sarasota, FL 4/21/90. Chemical Senses, 1990, 15.
34. Lawless, H. T. Bridging the gap between sensory science and product evaluation. Institute of Food Technologists Basic Symposium "Advances in Sensory Science." Anaheim, CA 6/17/90. (symposium co-chair)

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35. Claassen, M. and Lawless, H. T. A comparison of descriptive methods for sensory analysis of fluid milk. IFT Annual Meeting, Dallas, TX 6/5/91. First Place (tie) in the Rose Marie Pangborn Graduate Paper Competition, 1991.
36. Williamson, D. M., Gravani, R. B. and Lawless, H. T. Home food preparation practices: Results of a National Consumer Survey. IAMFES Annual Meeting, Louisville, KY 7/22/91. Fourth place in IAMFES Developing Scientist Competition. IAMFES Abs. 46: 13.
37. Lawless H. T. 1992. Characterization of Odor Quality by Multidimensional Scaling Techniques. 1992 IFT/IUFoST Basic Symposium, "Flavor Measurement." New Orleans, LA, 6/23/92. Food Technology, 46, 50. (invited)
38. Lawless, H. T. Psychological Biases in Time-Intensity Scaling. 1992 Annual Meeting, Institute of Food Technologists, Symposium on Time-Related Sensory Measurements, New Orleans, LA, 6/22/92. (Symposium Co-Chair)
39. Chen, J. H., Hotchkiss, J. H. and Lawless, H. T. Sensory and microbiological quality of cottage cheese packaged in high-barrier films with added CO<sub>2</sub>. 1992 Annual Meeting, American Dairy Science Association. J. Dairy Sci. 75 (suppl.1): D18, p. 95.
40. Lawless, H. T. Unexpected congruence in odor quality and intensity ratings. 1992 Annual Meeting, Association for Chemoreception Sciences, Sarasota, FL 4/18/92. Chemical Senses, 17, 657 - 658, 1992.
41. Claassen, M. R. and Lawless, H. T. Use of descriptive analysis as an alternative to dairy judging methods for the sensory evaluation of fluid milk defects. 1992 Annual Meeting, Institute of Food Technologists, New Orleans, LA, 6/22/92.
42. Stoer, N. R. and Lawless, H. T. A comparison of absolute and relative-to-reference scaling methods for the evaluation of dairy products. 1992 Annual Meeting, Institute of Food Technologists, New Orleans, LA, 6/23/92
43. Lawless, H. T. Training Sensory Scientists. Rose Marie Pangborn Memorial Symposium, Advances in Sensory Science, Jarvenpää, Finland. 8/6/92. (invited).
44. Corrigan, C. and Lawless, H. T. Sensory evaluation terminology and the semantics of astringency. Annual meeting, American Society for Enology and Viticulture, Eastern Section, Corning, NY 6/16/92.
45. Lawless, H. T. Opportunities for enhancement of dairy product evaluation. Annual meeting, New York State Association of Milk and Food Sanitarians. Saratoga, NY 9/23/92. Newsletter, NY State Association of Milk and Food Sanitarians, 36(4), 25, 1993.
46. Miller, D. K., Smith, V. L., Kanner, J., Miller, D.D. and Lawless, H. T. Effect of iron supplementation of swine rations on lipid oxidation and warmed-over aroma in cooked ground

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- pork. 1992 International Food Technology Exposition and Conference, (IFTEC) 67:106. The Hague, The Netherlands. 11/15/92.
47. Corrigan, C. and Lawless, H. T. Time-intensity measurements of astringent subqualities in selected organic and inorganic acids. 1993 Annual Meeting, Association for Chemoreception Sciences. Sarasota, FL.
  48. Lawless, H. T., Johnston, M., Corrigan, C. and Antinone, M. Specific anosmia: Practical significance? 1993 Annual Meeting, Association for Chemoreception Sciences. Sarasota, FL. Chemical Senses, 18, 586 - 587.
  49. Clark, C. C. and Lawless, H. T. Context and attribute response restriction: Psychological biases influencing time-intensity scaling. 1993 Annual Meeting, Association for Chemoreception Sciences. Sarasota, FL.
  50. Thomas, G. A., Gravani, R. B., McLaughlin, E. W. and Lawless, H. T. Food store delicatessen practices: Report of a two chain survey. 1993 Annual Meeting, IAMFES.
  51. Phillips, L. G., McGiff, M. L., Barbano, D. M. and Lawless, H. T. Characterizing the sensory and rheological attributes required of a fat substitute for fluid milk. 1993 Annual Meeting, Institute of Food Technologists, Chicago, IL. IFT Abstracts, No. 129, p. 36
  52. Wright, K. and Lawless, H. Attribute discovery and perceptual mapping: A comparison of techniques. 1993 Annual Meeting, Institute of Food Technologists, Chicago, IL.
  53. Sheng, N. and Lawless, H. T. Application of sorting and multidimensional scaling in the exploration of consumer cheese perception. 1993 Annual Meeting, Institute of Food Technologists, Chicago, IL.
  54. Phillips, L. G., McGiff, M. L., Barbano, D. M. and Lawless, H. T. The sensory attributes of skim milk containing nonfat dry milk. 1993 Annual Meeting, American Dairy Science Association. College Park, MD. J. Dairy Sci. 76: Suppl. 1, p. 128.
  55. Lawless, H. T. and Corrigan, C. J. Semantics of Astringency. 11th International Symposium on Olfaction and Taste and 27th Japanese Symposium on Taste and Smell, Sapporo, Japan, 7/15/93.(invited)
  56. Lawless, H. T. Getting results you can trust. Annual Meeting, American Association of Cereal Chemists, Miami, FL 10/7/93. (invited)
  57. Antinone, M.J., Lawless, H. T., Ledford, R. A. and Johnston, M. The importance of diacetyl as a flavor component in full fat cottage cheese. 1993 Annual Meeting, American Dairy Science Association. College Park, MD. J. Dairy Science 76 (suppl.1):106.
  58. Lawless, H. T. The central dogma of sensory evaluation and basic psychological principles. Canadian Institute of Food Science and Technology, Toronto, ON. 6/18/93(invited)

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59. Lawless, H. T. Getting down to brass tacks. European Sensory Trade Fair, Birmingham, U.K. 11/18/93. (invited)
60. Thomas, G. A., Gravani, R. B., McLaughlin, E. W. and Lawless, H. T. 1993. The impact of employee food sanitation knowledge and handling practices on the supermarket deli profitability. Proceedings, International Association of Milk, Food and Environmental Sanitarians (IAMFES) Annual Meeting Abs. 84:37.
61. Lawless, H. T. and Knoop, S. S. C. P. Qualitative sensory variation in blue cheeses assessed by sorting and multidimensional scaling. 1994 Annual Meeting, Institute of Food Technologists, Chicago, IL. IFT Annual Meeting Abs. #69-3, p.150.
62. Lui, Y. F. and Lawless, H. T. 1994. Reliability and variability of small panel wine hedonic and quality assessments. 1994 Annual Meeting, Institute of Food Technologists, Chicago, IL. IFT Annual Meeting Abs. #12C-2, p.29.
63. El-Gharby, A. H. and Lawless, H. T. The influences of attitudes, beliefs and eating restraint on perceptions of non-fat yogurt. 1994 Annual Meeting, Institute of Food Technologists, Chicago, IL. IFT Annual Meeting Abs. #69-4, p.150.
64. Lawless, H. T. and Corrigan, C. C. Principal Components Analysis of Astringency and Sourness Ratings of Acids, Alums and Mixtures. 1994 Annual Meeting, Association for Chemoreception Sciences, Sarasota, FL. Chemical Senses, 19: 504. Abstract # 161
65. Corrigan, C. C. and Lawless, H. T. Influence of Oral Volume Capacity on Perception of Astringent Intensity. 1994 Annual Meeting, Association for Chemoreception Sciences, Sarasota, FL. Chemical Senses, 19: 455 - 456. Abstract # 53
66. Phillips, L. G., Barbano, D. M. and Lawless, H. T. The sensory attributes of skim milk containing a fat substitute. 1994 Joint Meeting, ADSA/ASAS. J. Dairy Sci. 77: Suppl. 1: p. 51.
67. Lawless, H. T., Shaffer, L. M. and Corrigan, C. J. Sensory aspects of cellulose. 1994 Annual Meeting, Institute of Food Technologists, Chicago, IL. (invited). IFT Annual Meeting Abs. #52-3, p.150.
68. Lawless, H. 1995. Qualitative sensory and consumer research. Food for the Consumer, Measurement of Consumer Attitudes, 1 (1), p. 59. AIR-CAT, Ås, Norway. (Proceedings, First Plenary meeting, Rome, Italy, 18 - 21 May, 1995).
69. Phillips, L. G., Barbano, D. G. and Lawless, H. T. 1995. The sensory attributes of skim milk containing a casein and titanium dioxide blend to improve whiteness. ADSA. J. Dairy Sci.: 78: Suppl. 1., p. 135.
70. Lawless, H. T. and Giasi, P. 1995. Astringency and Sourness of Buffered Acids. 1995 Annual Meeting, Association for Chemoreception Sciences. Chemical Senses, 20, p. 728.

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71. Lawless, H. T. 1996. Relative Effect Size in Sensory Evaluation. Second Pangborn Symposium on Sensory Science, 1995. Food Quality and Preference, 7, 309.
72. Lawless, H. T. and Horne, J. 1996. Context effects and the labeled magnitude scale. Association for Chemoreception Sciences, 1996. Chemical Senses, 21, 629 - 630.
73. Inn, B. Y. and Lawless, H. T. 1996. Relationships between salivary responses and astringency, bitterness and sourness responses to aluminum ammonium sulfate. Association for Chemoreception Sciences, 1996. Chemical Senses, 21, 618.
74. Thomas, C. J. C. and Lawless, H. T. 1996. Stimulus quantity, mouth size and perception of astringent intensity. Second Pangborn Symposium on Sensory Science, 1995. Food Quality and Preference, 7, 334.
75. Hernandez, S. V. and Lawless, H. T. 1997. Preference levels of capsaicin in liquid and solid food systems of two ethnic groups. Activities Report, R&D Associates, 49 (1), 116.
76. Lawless, H. T., Hartono, C. and Hernandez, S. 1998. Human Response to Capsaicin in Oil and Water Based Carriers. Association for Chemoreception Sciences, Annual Meeting, Chemical Senses 23, 619.
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78. Lawless, H. T., Hartono, C. Horne, J. and Siebert, K. J. 1999. Interactions of tannins and human salivary proteins assessed by turbidimetry. Association for Chemoreception Sciences, Annual Meeting, Chemical Senses, 24, 543 - 544.
79. Olabi, A. Hunter, J. B., Lawless, H. T. and Levitsky, D. A. 1999. Effect of space flight and microgravity on the stimulation of the chemical senses: Association for Chemoreception Sciences, Annual Meeting, Chemical Senses, 24, 609 - 610.
80. Sposato, D. J. and Lawless, H. T. 2000. Individual differences in bitter taste perception of saccharin and acesulfam-K. Association for Chemoreception Sciences, Annual Meeting, Chemical Senses, 25, 640.
81. C. A. Pelletier and H. T. Lawless. 2001. Sweet-sour Mixture Suppression in the Elderly, International Society for Olfaction and Taste, Brighton, England, 7/00. Chemical Senses, 26, 782 - 783.
82. Taste Acceptance Scales in the Nursing Home. C. A. Pelletier and H. T. Lawless. International Meeting on Food Choice, Dublin, Ireland, 7/00. In Press, Food Quality and Preference.

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83. Sposato, D. J., Horne, J., Speirs, W. F. and Lawless, H. T. 2001. Effects of labeled magnitude scale instructions on taste perception of Na-saccharin, acesulfame-K and 6n-propylthiouracil. Association for Chemoreception Sciences, Chemical Senses, 26, 1069.
84. Rapacki, F. M., Hayes, A., Wang, G. and Lawless, H. T. 2001. Taste properties of calcium salts and mixtures. Association for Chemoreception Sciences, Chemical Senses, 26, 1070.
85. Lawless, H. T., Schlake, S. and Smythe, J. 2003. Metallic taste of ferrous sulfate: A case of retronasal smell and gustatory referral? European Chemoreception Organization, Annual Meeting, Erlangen, Germany, 7/02. Chemical Senses, 28, 74, full text in [www.chemse.oupjournals.org](http://www.chemse.oupjournals.org).
86. Pelletier, C. P. and Lawless, H. T. Effect of citric acid and citric-acid sucrose mixtures on swallowing in neurogenic oropharyngeal dysphagia. Dysphagia Research Society, Annual Meeting, Oct. 3 - 5, 2003, Miami, FL.
87. Lawless, H. T. and Stevens, D.A. 2004. Electric Stimulation and Metallic Taste. Association for Chemoreception Sciences, Sarasota, FL 4/22/04.
88. Lawless, H. T. 2004. Consumer Testing of Food Products: Principles and Applications. University of Costa Rica. International Congress on Food Product Development, San Jose, Costa Rica, 4/30/04.
89. Lim, J. and Lawless, H. T. 2004. Metallic sensations from oral and retronasal perception of ferrous sulfate. Institute of Food Technologists Annual Meeting Las Vegas, Nevada. 7/15/04.
90. Chapman, K. and Lawless, H. T. 2004. Correlation of instrumental measures of saliva turbidity and perceived astringency of metallic salts. Institute of Food Technologists Annual Meeting, Las Vegas, Nevada 7/15/04.
91. Lawless, H. T. 2005. Sensory Modalities of Metallic Taste, Seventh Pangborn Symposium on Sensory Science, Harrogate, UK, 8/8/05.
92. Lawless, H. T. and Chapman, K. W. 2005. Sources of Error Variance in Consumer Tests of Dairy Product Preferences, Institute of Food Technologists, Annual Meeting, 7/19/05.
93. McClure, S.T., Lawless H.T., 2006. Calibration of a lingual electric stimulator, laterality of response and metallic taste. Association for Chemoreception Sciences, Annual Meeting, 4/28/06.
94. Stevens, D.A., Curnoni, E.R., Frey, A.M., Lawless, H.T. 2006. Comparison of responses to electrical and chemical stimuli. Association for Chemoreception Sciences, Annual Meeting, 4/28/06.

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### Other Technical Publications

#### Books (2):

Sensory Evaluation of Food, Principles and Practices. H. T. Lawless and H. Heymann, Chapman & Hall, 1997.

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#### Chapters, Contributions to Edited Volumes and Proceedings (23):

Lawless, H. T. 2001. Sensory Evaluation of Cheese. In Cheese Art 2000, Proceedings of Atti del Flavor Workshop, "Gli Aromi come Marcatori della Biodiversità", Ragusa, Sicily, Consozio Ricerca Fileira Latteiro-Casearia di Ragusa, pp. 60 - 67.

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Lawless, H. T. 2000. Sensory Combinations in the Meal. In: Dimensions of the Meal, H. L. Meiselman, Ed. Gaithersburg, MD: Aspen Publishers, pp. 92 - 106.

Lawless, H. T. 1997. Olfactory Psychophysics. In: Handbook of Perception and Cognition, Tasting and Smelling. G. K. Beauchamp and L. M. Bartoshuk, Eds. San Diego: Academic Press, pp. 125 - 174.

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Lawless, H. T. 1991. Bridging the gap between sensory science and product evaluation. In: Sensory Science: Theory and Application in Foods, H. T. Lawless and B. P. Klein (Eds.). pp. 1 - 36. New York: Marcel Dekker.

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Lawless, H. 1995. Commentary on *The Cognitive Basis of Quality*, by David Booth. *Food Quality and Preference* 6(3), 205 - 207.

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Lawless, H. 1994. Review of "Dietary Fats. Determinants of Preference, Selection and Consumption, D. J. Mela, Ed. *Appetite*, 22, 97.

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Lawless, H. 1996. Review of "Design and Analysis of Sensory Optimization" M. C. Gacula, Jr. Journal of Texture Studies.

Editorial Essays in the Sensory Forum, Newsletter of the Sensory Evaluation Division, Institute of Food Technologists:

Lawless, H. "On testmanship." December, 1987, Sensory Forum.

Lawless, H. "Reflections on sensory methods research." March, 1988, Sensory Forum.

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